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- Parabolic Primary Mirror
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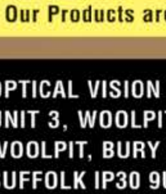
Sir Patrick Moore Endorsed Sky-Watcher Telescopes



> *"I have used a great number of telescopes; some are good, some mediocre and some bad. To me the Sky-Watcher range of instruments are very good indeed, & suited to amateurs of all kinds - and they are not priced out of the market! Excellent value. Use them and enjoy them."*
> **Sir Patrick Moore CBE FRS (1923-2012)**

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This month, Neil deGrasse Tyson chats to **All About Space**

Discover the wonders of the universe

The universe hosts many mysteries, but, perhaps one of the biggest is dark energy. Accounting for 68.3 per cent of the cosmos, this force is pushing space apart, driving the expansion of the universe that sees galaxies racing away from us.

Ever since Albert Einstein proposed dark energy, scientists have been scratching their heads about what it really is, what it could look like, and how it could determine the fate of the universe. **All About Space** meets the scientists who have made some head way in understanding more about the universe's biggest-ever mystery over on page 16.

Elsewhere in the issue, we reveal the stars due to explode in an astronomically-short time with a force that's not too dissimilar to trillions of megatons of TNT. From red supergiant Betelgeuse to near-Earth IK Pegasi, check out the top ten of our Sun's stellar cousins that are scheduled to go supernova. Of course, we're unlikely to see these cosmic detonations – you'll find out why as we look ahead to the future of our Solar System on page 38, where Mars' moon Phobos becomes a ring around the Red Planet and Earth meets its end as the Sun swells into a huge red giant.

This month, we also speak to Toni Myers, a Hollywood film director, about her role in bringing three-dimensional space docufilms to the IMAX, including *Hubble 3D*, as well as astrophysicist Neil deGrasse Tyson, who talks to us about a holographic universe, multiverses and his musings on the likelihood of alien life – much more intelligent than us – visiting our home planet. He also found time to talk about his debut on DreamWorks' *Ice Age: Collision Course*.

Gemma Lavender
Editor

Contributors

Kulvinder Singh Chadha

What have we uncovered about dark energy? Kulvinder speaks to the experts who are bringing us closer to understanding it.

Ben Evans

Did you know there are ten stars due to go supernova in an astronomically-short time? We reveal which of our Sun's stellar cousins are due to explode.

Giles Sparrow

In time, Mars will gain a ring and our home planet with meet its end. And that's not all – find out what else Giles discovered about the future of our Solar System over on page 38.

Colin Stuart

Colin gets an update from the scientists who are working on the concepts behind interstellar travel, which star systems we're headed to, and what's required to become a space tourist.

> "To imagine yourself as a simulation, within a universe that's also a simulation, pretend you're in a video game"
>
> **Neil deGrasse Tyson, astrophysicist [page 34]**

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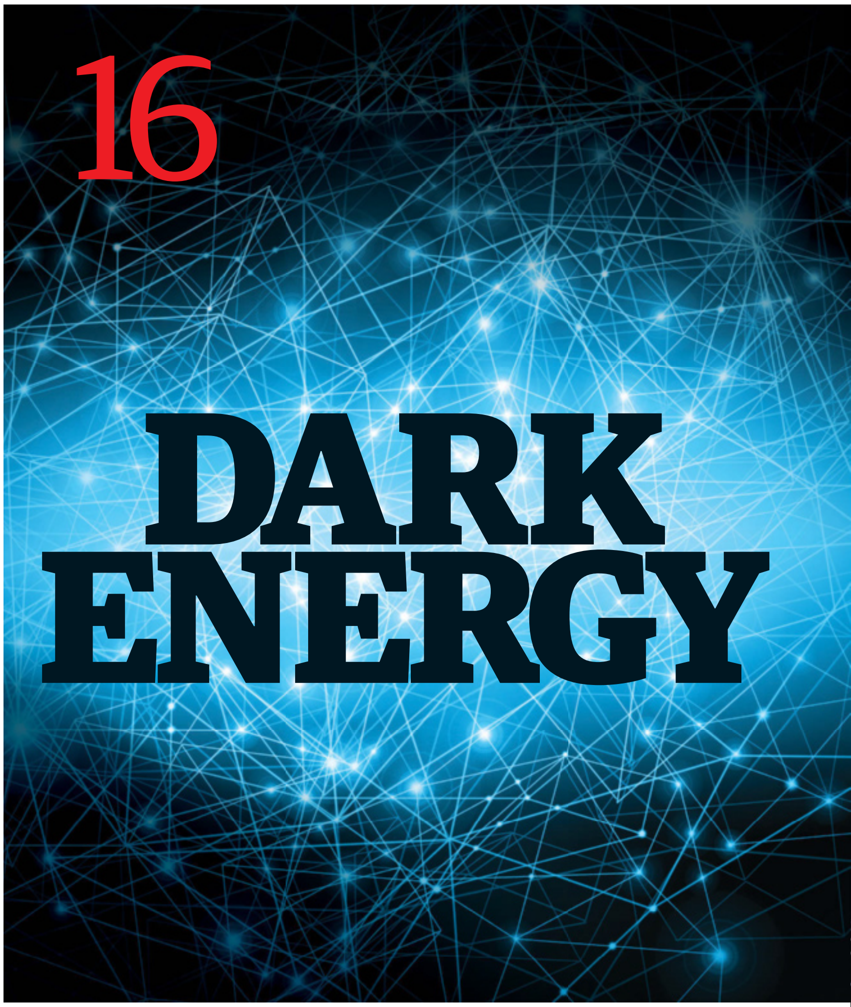

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> “I’m intrigued by the idea that we are a record of something playing out in another way inside of a black hole”

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LAUNCH PAD
YOUR FIRST CONTACT WITH THE UNIVERSE

Moonrise from the International Space Station

The commander of Expedition 48, Jeff Williams of NASA, took this spectacular rise of the full Moon just before sunset while flying over western China.

Expedition 48 began upon the departure of Expedition 47, which consisted of Yuri Malenchenko, Tim Peake and Tim Kopra, and also includes Alexey Ovchinin and Oleg Skripochka of Russian Space Agency, Roscosmos. When Williams returns to Earth this coming August, he will have completed over 520 days in space, racking up more days in Earth orbit than Scott Kelly. Also flying with the Expedition 48 crew will be a stuffed pink owl, which belongs to Ovchinin's daughter.

@NASA

Orion makes a splashdown

In this image, a test version of the Orion spacecraft – which will be used for future manned missions to Mars – is released, causing it to take a dive into a 6.1-metre (20-foot) deep Hydro Impact Basin at NASA's Langley Research Center in Hampton, Virginia.

To make the mission much more authentic, crash-test dummies, wearing modified Advanced Crew Escape Suits, were seated inside the capsule in order to help engineers work out how a splashdown in the ocean on return from a deep-space mission would impact the interior and the crew. NASA scientists will run a series of water-impact test scenarios on the Orion capsule including varying wind conditions, speeds and wave heights.

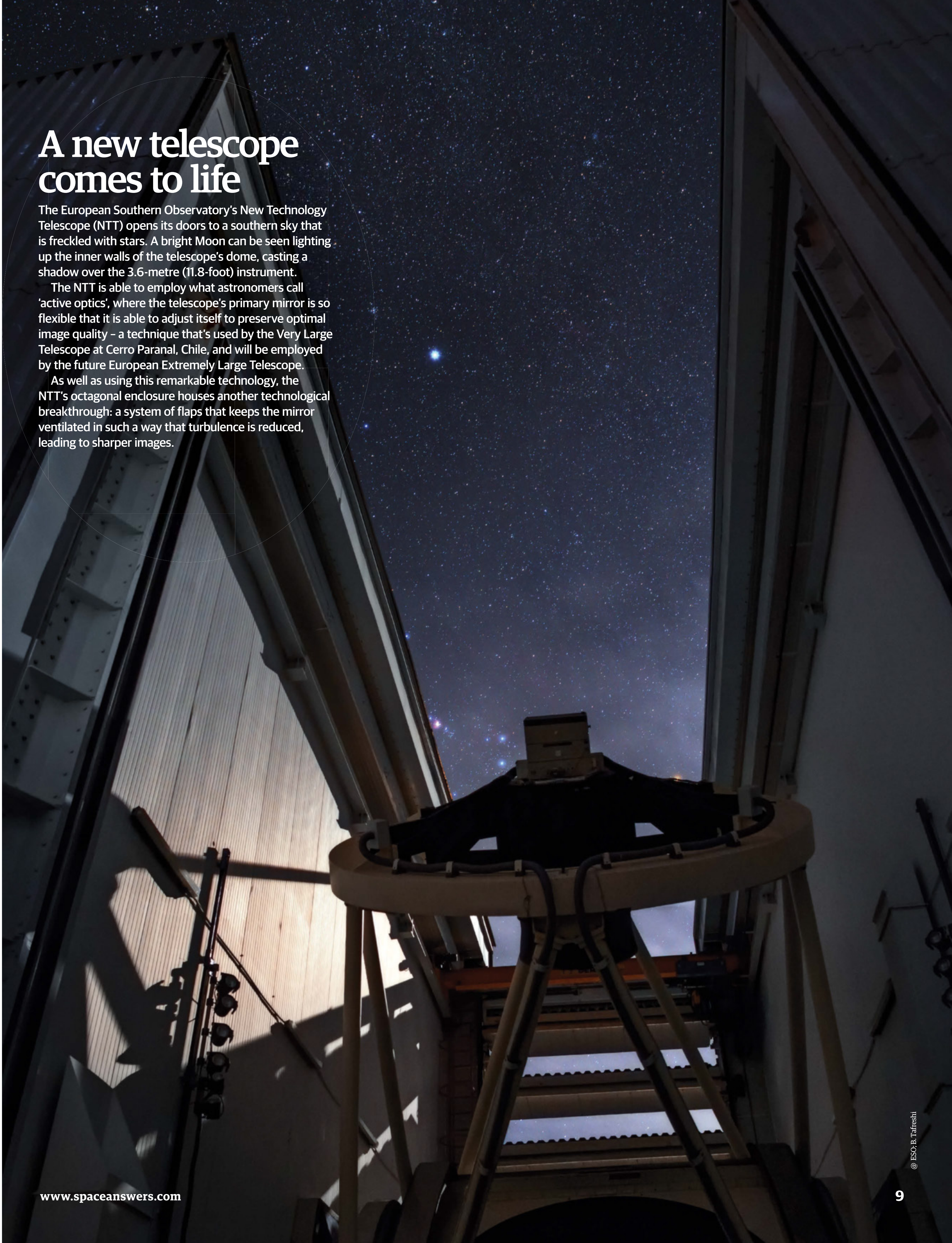
@ NASA

Sentinel enters the space chamber

The European Space Agency's (ESA's) Sentinel-2B Earth-observing satellite is lowered into Europe's largest vacuum chamber to begin its testing to ensure it is space-worthy.

Now within ESA's 15-metre (49.2-foot) wide Large Space Simulator, all air within the chamber makes an orbital-quality vacuum, while liquid nitrogen circulates through the testing facility's black walls in order to mimic frigid, sunless space. The spacecraft is the twin to Sentinel-2A, which launched a year ago – together, the pair will provide valuable data on planet Earth's vegetation and coastal waters, and will return their findings quickly to ground control via laser communications.

@ ESA/G. Porter



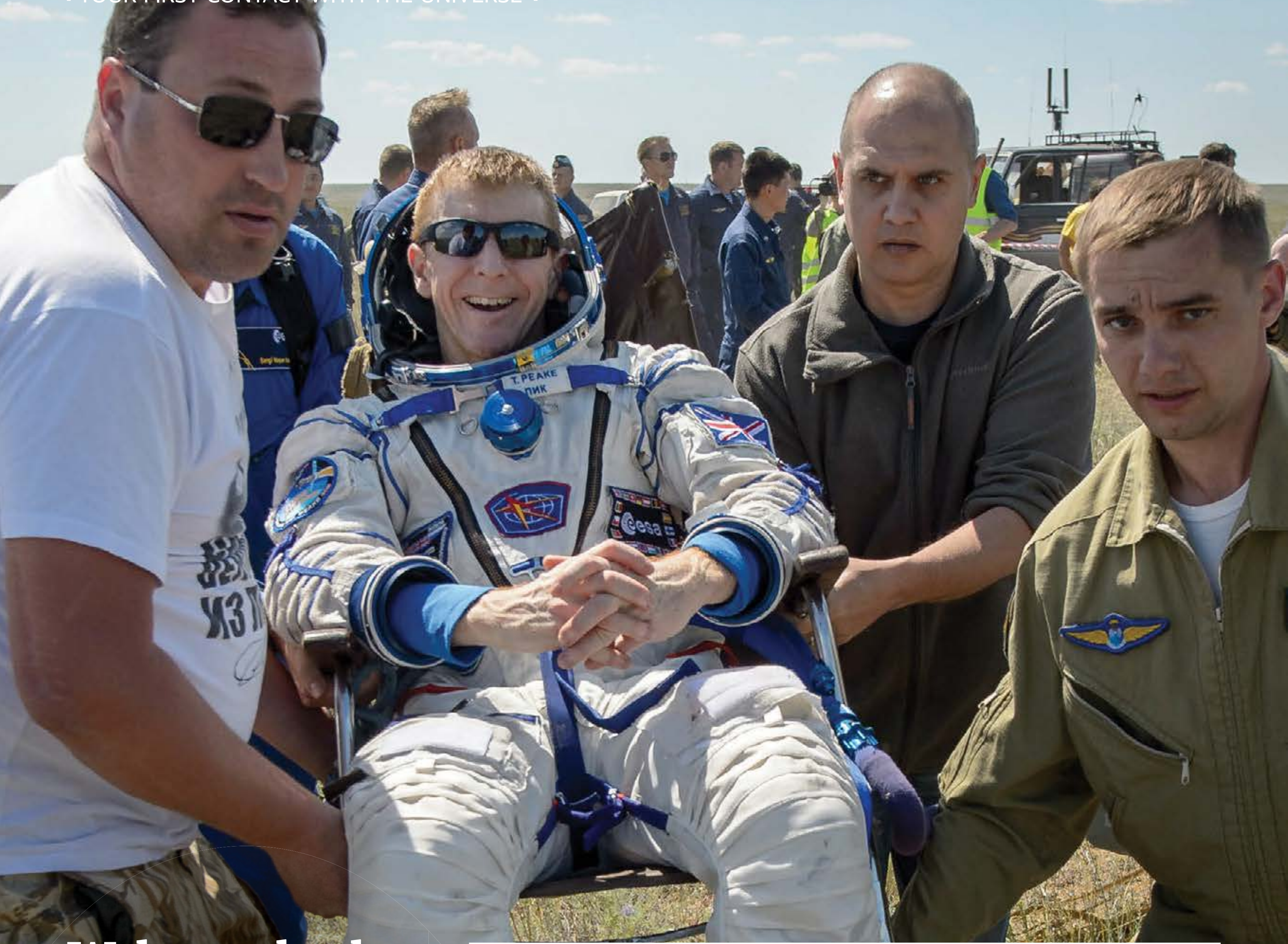
A new telescope comes to life

The European Southern Observatory's New Technology Telescope (NTT) opens its doors to a southern sky that is freckled with stars. A bright Moon can be seen lighting up the inner walls of the telescope's dome, casting a shadow over the 3.6-metre (11.8-foot) instrument.

The NTT is able to employ what astronomers call 'active optics', where the telescope's primary mirror is so flexible that it is able to adjust itself to preserve optimal image quality – a technique that's used by the Very Large Telescope at Cerro Paranal, Chile, and will be employed by the future European Extremely Large Telescope.

As well as using this remarkable technology, the NTT's octagonal enclosure houses another technological breakthrough: a system of flaps that keeps the mirror ventilated in such a way that turbulence is reduced, leading to sharper images.

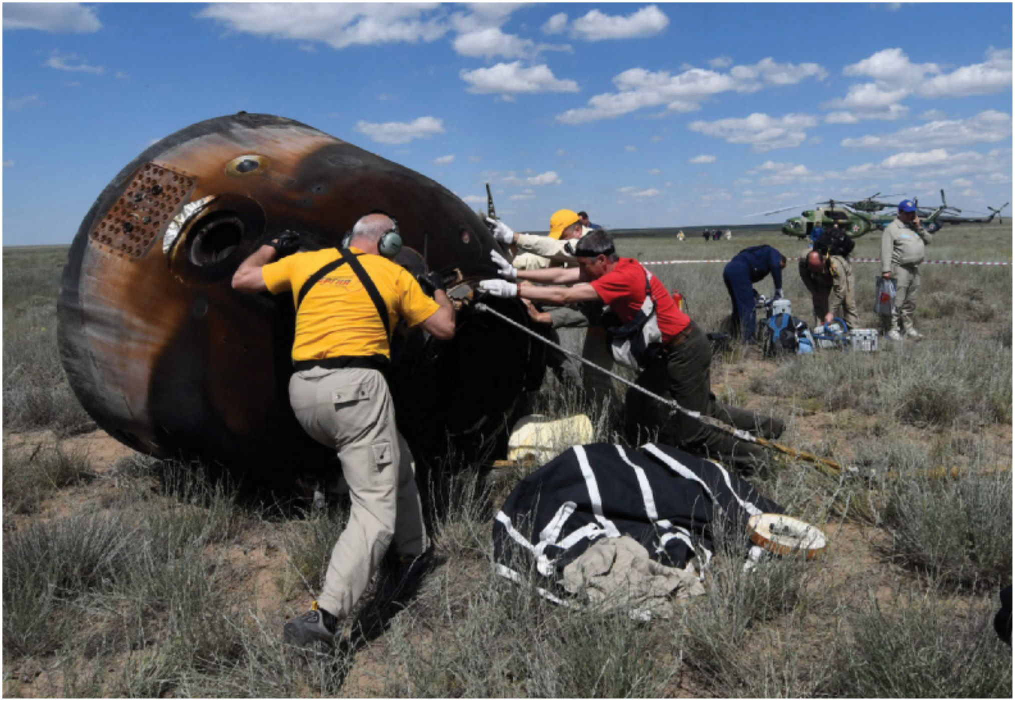
@ ESO/B. Tafreshi



Welcome back, Tim Peake!

After arriving back on Earth on 18 June in a Soyuz TMA-19M spacecraft with International Space Station crew members Tim Kopra of NASA and Yuri Malenchenko of Roscosmos, Tim Peake of the European Space Agency gives a broad smile as he is carried to a medical tent not far from the landing site: a remote area near the town of Zhezkazgan, Kazakhstan.

Serving as a member of Expedition 46 and 47 onboard the Space Station for six months, Peake began his reentry into the Earth's atmosphere at around 120 kilometres (75 miles). Their cruising speed of 28,800 kilometres (17,895 miles) per hour was reduced dramatically, with the British astronaut and his crew pushed back into their seats with a force that's equivalent to four to five times their own body weight. Thanks to a parachute (inset), the astronauts could reduce their speeds even further for landing, also aided by their custom-fitted seats that absorbed the shock of impact.



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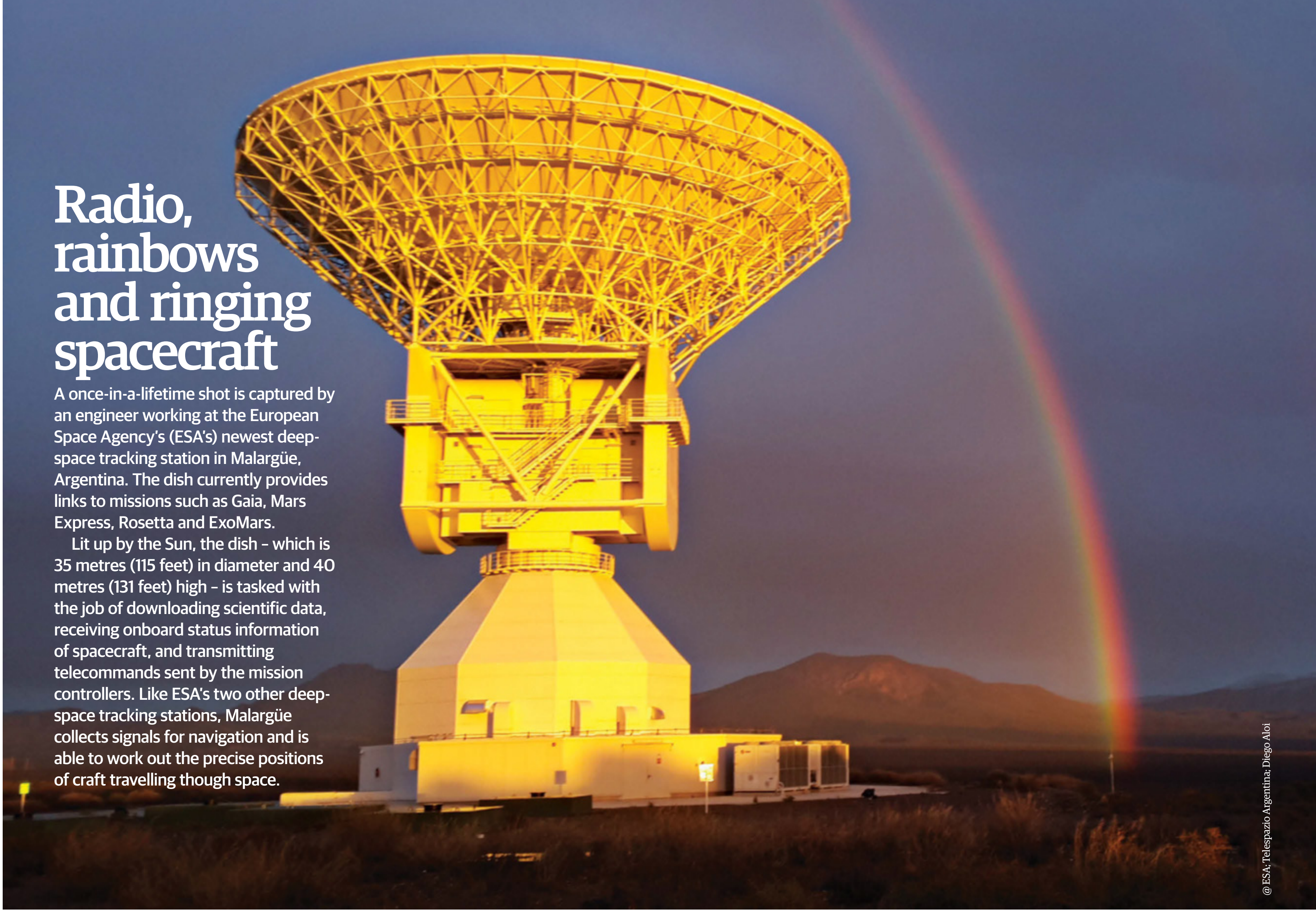
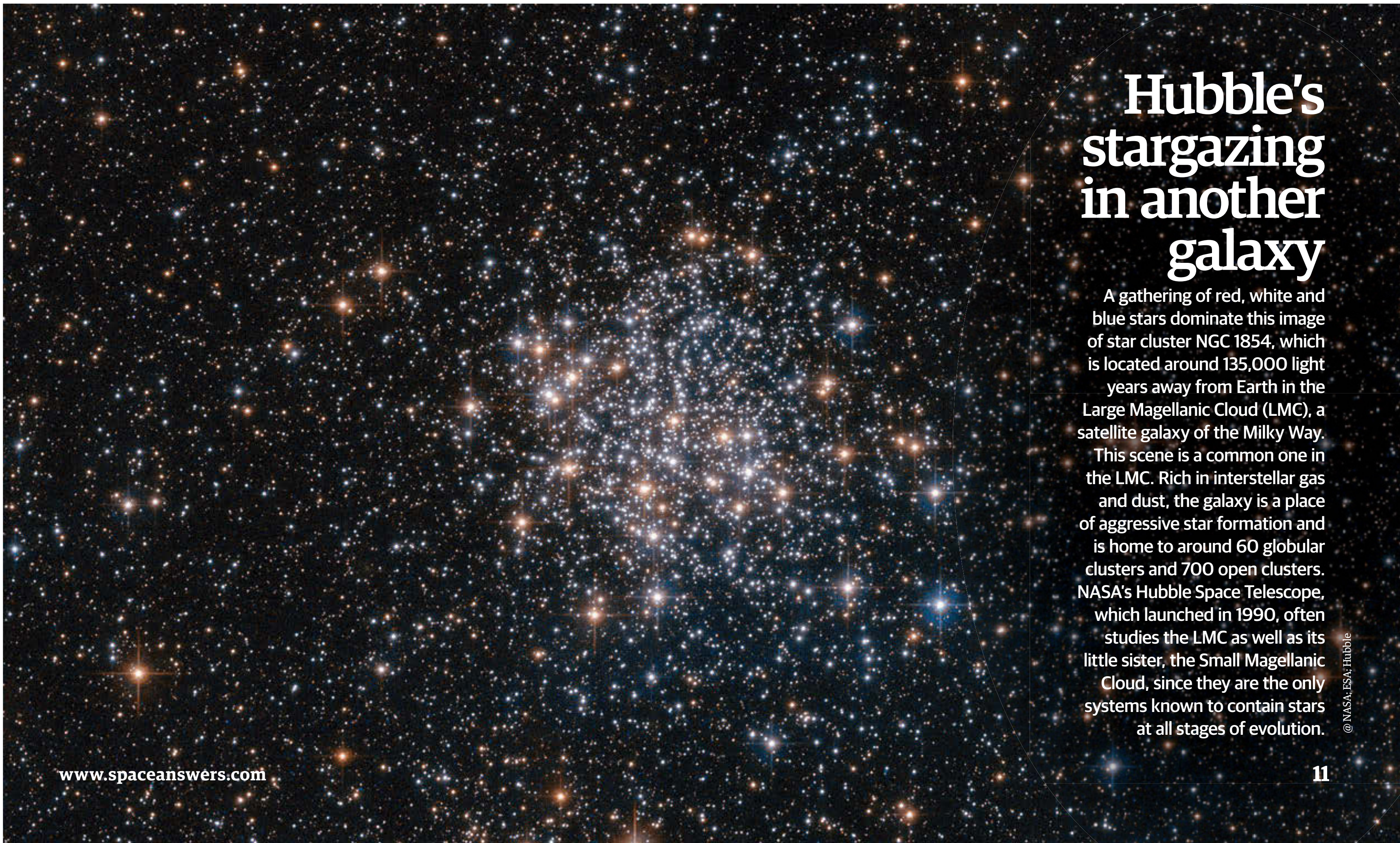


Radio, rainbows and ringing spacecraft

A once-in-a-lifetime shot is captured by an engineer working at the European Space Agency's (ESA's) newest deep-space tracking station in Malargüe, Argentina. The dish currently provides links to missions such as Gaia, Mars Express, Rosetta and ExoMars.

Lit up by the Sun, the dish – which is 35 metres (115 feet) in diameter and 40 metres (131 feet) high – is tasked with the job of downloading scientific data, receiving onboard status information of spacecraft, and transmitting telecommands sent by the mission controllers. Like ESA's two other deep-space tracking stations, Malargüe collects signals for navigation and is able to work out the precise positions of craft travelling though space.

@ ESA; Telespazio Argentina; Diego Aloi



Hubble's stargazing in another galaxy

A gathering of red, white and blue stars dominate this image of star cluster NGC 1854, which is located around 135,000 light years away from Earth in the Large Magellanic Cloud (LMC), a satellite galaxy of the Milky Way. This scene is a common one in the LMC. Rich in interstellar gas and dust, the galaxy is a place of aggressive star formation and is home to around 60 globular clusters and 700 open clusters. NASA's Hubble Space Telescope, which launched in 1990, often studies the LMC as well as its little sister, the Small Magellanic Cloud, since they are the only systems known to contain stars at all stages of evolution.

@ NASA; ESA; Hubble

'Dreaming' robot to seek out habitable worlds

Currently under development, RobERt will sift through an enormous amount of data collected on distant exoplanets

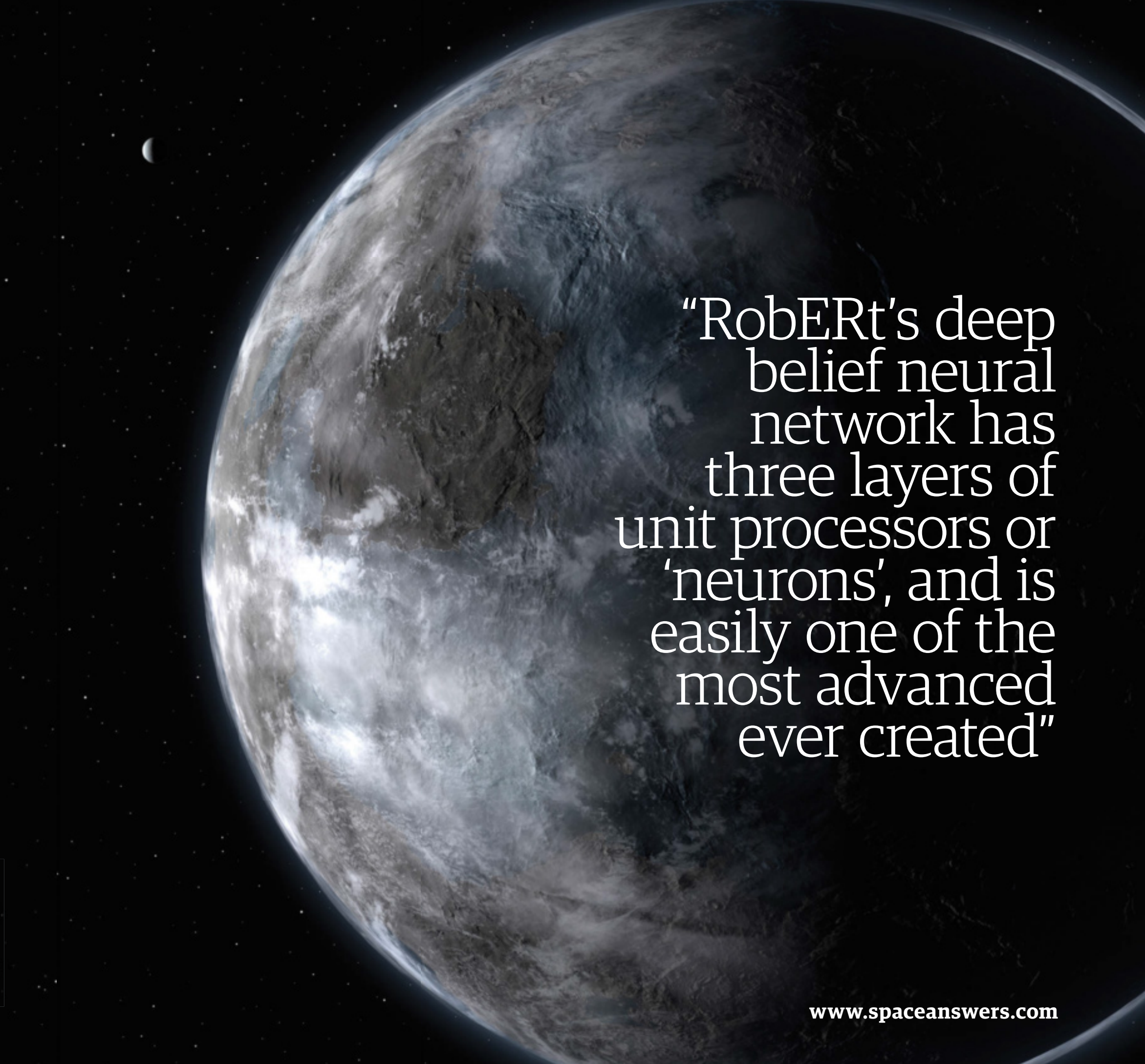
A new deep belief neural network (DBN) has been developed by University College London in order to seek out habitable worlds. Named RobERt (Robotic Exoplanet Recognition), the machine's artificial intelligence detects light emanating from distant planetary systems and retrieves spectral information regarding the gases present in these exoplanet atmospheres.

"Different types of molecules absorb and emit light at specific wavelengths, embedding a unique pattern of lines within the electromagnetic spectrum," explains Dr Ingo Waldmann, leader of RobERt's development team. "We can take light that has been filtered through an exoplanet's atmosphere or reflected from its cloud-tops, split it like a rainbow and then pick out the 'fingerprint' of features associated with the different molecules or gases."

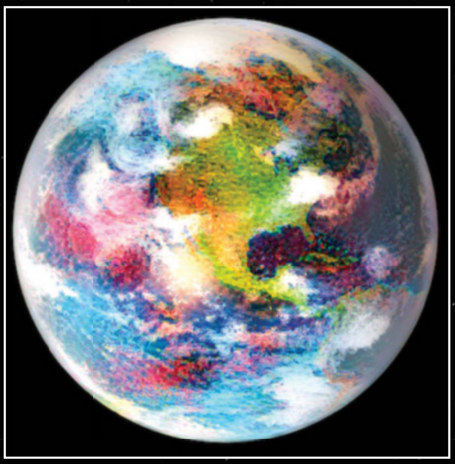
"Human brains are really good at finding these patterns in spectra and label them from experience, but it's a time-consuming job and there will be huge amounts of data," he adds. "We built RobERt to independently learn from examples and build on his own experiences. This way, like a seasoned astronomer or a detective, RobERt has a good feeling for what molecules are inside a spectrum and which is the most promising data for more detailed analysis. But what takes humans days or weeks takes RobERt mere seconds."

DBNs have been around for over a decade and are often found in speech recognition software and search engines. RobERt's DBN, which has three layers of unit processors or 'neurons', is one of the most advanced ever created. Information enters a layer of 500 neurons, which make an initial filter of the data and pass a section of it up to the next layer. Here, 200 more neurons refine the data subset and send it to a third layer of 50 neurons to make the final identification of any present gases.

RobERt's performance was tested using a complex scenario of simulated data: it used 85,750 predetermined spectra covering five types of exoplanet, with each containing traces of a single gas. The results have been positive, with the DBN achieving a 99.7 per cent overall accuracy.



"RobERt's deep belief neural network has three layers of unit processors or 'neurons', and is easily one of the most advanced ever created"



The DBN can also be 'reversed', enabling RobERt to enter a so-called dream state where it can generate its own spectra based on the data it's 'experienced'

Rovers could image potential water sites on Mars, says NASA

The space agency is weighing up the risks and benefits of seeking out liquid on the Red Planet

Following the data collected by the Mars Reconnaissance Orbiter (MRO) in 2015, which presented the strongest evidence yet that liquid water flows on modern day Mars, NASA is now discussing potential options to seek out these long-rumoured sources - including the use of the Curiosity rover.

"It's not as simple as driving a rover to a potential site and taking a scoop of soil," says Jim Green, NASA's director of planetary science. "Not only are these on steep slopes, we need to ensure that planetary protection concerns are met. In other words, how can we search for evidence of life without contaminating the sites with bugs from Earth?"

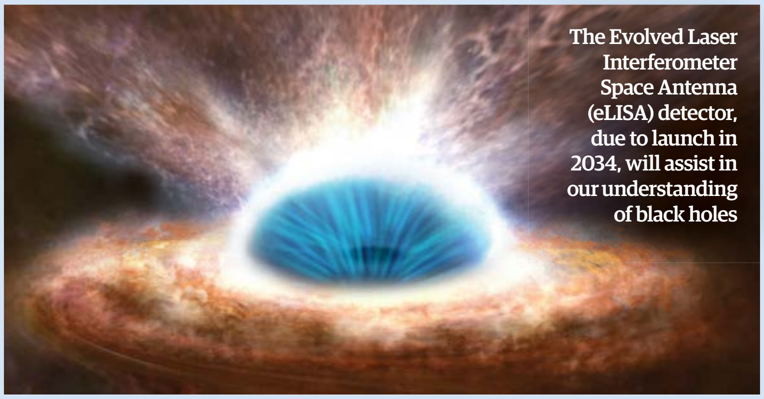
These potential water sites, which appear as dark streaks on the images captured by the MRO, are believed to be recurring slope lineae (or RSLs) caused by tracts of liquid water. NASA believes the Curiosity rover could make the distance to some of these locations, but that means tackling some ridges and slopes that may be too much for it.

So how close could the rover safely get to an RSL? "That's exactly the question that needs to be addressed early in the process," comments Catharine Conley, NASA's planetary protection officer. "Kilometres away - it's unlikely that it would be an issue. But in terms of coming much closer, we need to understand well in advance the potential for Earth organisms to come off the rover, and that will tell us how far away the rover should stay."

NASA considers these RSLs 'special sites' and is taking every precaution not to contaminate potential Martian sources of water

Space-time ripples may unlock origins of supermassive black holes

The seeds of these destructive phenomena may be traceable thanks to gravitational waves



The Evolved Laser Interferometer Space Antenna (eLISA) detector, due to launch in 2034, will assist in our understanding of black holes

Gravitational waves could be used to track how supermassive black holes are born, according to a team of researchers based at Durham University's Institute for Computational Cosmology. The astronomers used data captured earlier in the year to create a new series of fascinating computer simulations.

"Understanding more about gravitational waves means that we can study the universe in an entirely different way," says PhD student Jaime Salcido. "These waves are caused by massive collisions between objects with a mass far greater than our Sun. By combining the detection of gravitational waves with simulations, we could ultimately work out when and how the first seeds of supermassive black holes formed."

Current theories suggest the first supermassive black holes were created by the heat deaths of the very first stars or in the fires caused by two or more of them colliding in those primordial years. However, according to Salcido and co-author Professor Richard Bower, this would cause very different wave patterns. Their own theory involves retroactively studying the amplitude and frequency of these gravitational waves to determine when and where in cosmological history these giants were formed.

"Black holes are fundamental to galaxy formation and are thought to sit at the centre of most galaxies, including our own," adds Bower. "Discovering how they came to be is one of the unsolved problems of cosmology and astronomy. Our research shows how space-based detectors will give new insights into the nature of black holes."

Space News in Brief

China prepares assembly of own space station

The People's Republic of China is preparing to construct its very own space station, and it's also hoping to invite the United Nations (UN) along for the ride too. The Chinese government has agreed to a partnership with the UN that will allow non-Chinese firms to help manufacture components for the new space station, in a bid to show its desire for international cooperation with the project.

Fire experiment ignited aboard space cargo ship

In order to further its understanding of fire and how it behaves in microgravity, NASA set fire to a strip of cotton-fibreglass on board an unmanned cargo ship in orbit around Earth. The Space Fire Experiment (Saffire-I), which took place on 14 June, is the largest fire experiment conducted in space and involved burning the flammable strip from one end to the other, which took around eight minutes.

Sea's 'whistle' can be heard from space

Scientists have recently discovered a sound that is generated in the waters of the Caribbean Sea, which is so loud that it can be 'heard' from space. The whistle sound, which is 28 octaves below the lowest note on a piano, is a frequency that is inaudible to the human ear yet it has been found to subtly affect the gravitational field of Earth.

Japanese firm plans rainbow-coloured meteors

Japanese company ALE is planning to launch a series of artificial meteors into space that will generate a multicoloured hue as they burn up in the Earth's atmosphere. ALE plans to carry 500 to 1,000 'source particles' into space aboard a satellite, with those particles then transforming into rainbow meteors.

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SETI listens to nearby stars for extraterrestrials

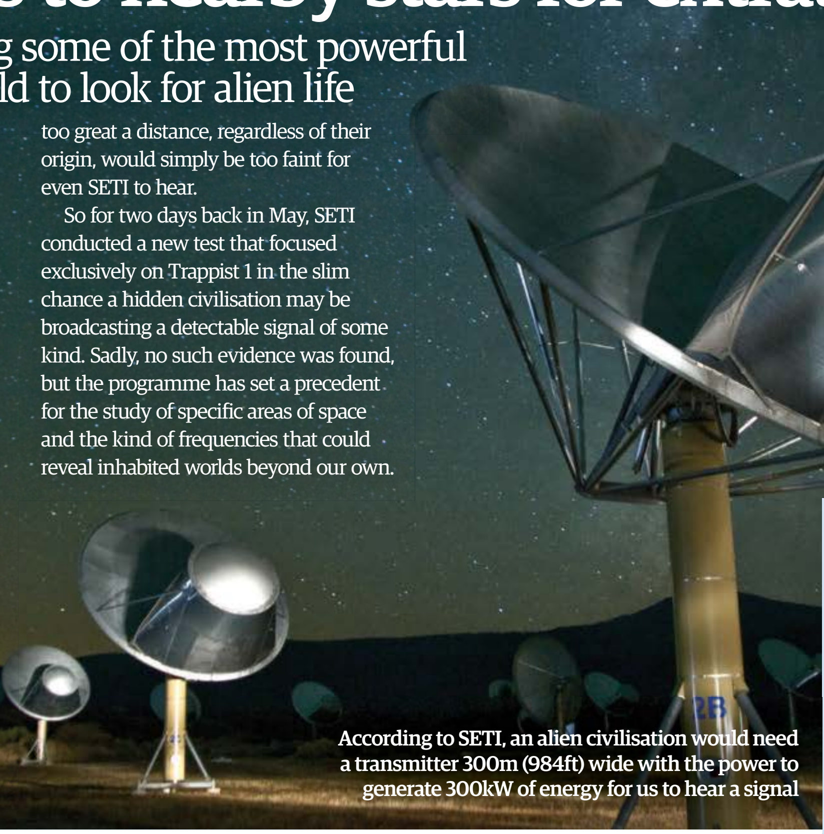
Astronomers are using some of the most powerful equipment in the world to look for alien life

Following the discovery of thousands of exoplanets surrounding our Solar System, members of the SETI Institute have been using the powerful Allen Telescope Array (ATA) in California to focus their attention on specific points in space rather than casting their celestial nets across a far broader area.

The SETI team has selected Trappist 1, a red dwarf type star, as the focus of their study, which we know has three separate exoplanets that exist within its 'habitable zone' (a portion of space around a star that offers enough light and warmth to potentially support life).

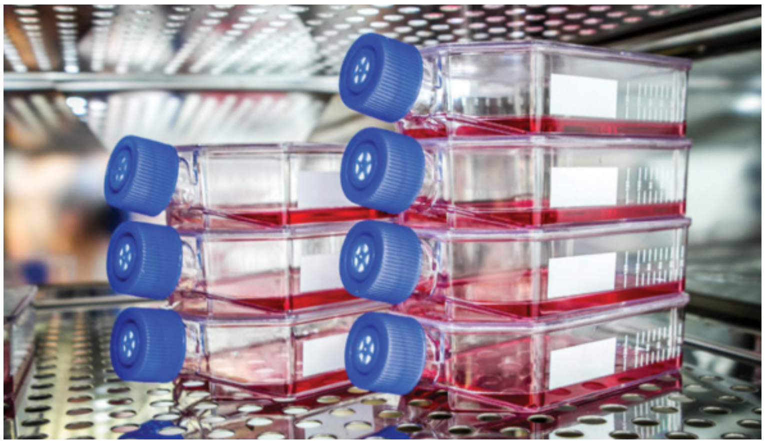
Specifically, astronomers are hoping to find traces of radio waves. However, such a desire would require an alien life form to be broadcasting a loud enough signal for arrays such as the ATA to detect, or have such devices pointed specifically in the direction of Earth. And the signals would need to be relatively near our planet for us to detect them – those at too great a distance, regardless of their origin, would simply be too faint for even SETI to hear.

So for two days back in May, SETI conducted a new test that focused exclusively on Trappist 1 in the slim chance a hidden civilisation may be broadcasting a detectable signal of some kind. Sadly, no such evidence was found, but the programme has set a precedent for the study of specific areas of space and the kind of frequencies that could reveal inhabited worlds beyond our own.


According to SETI, an alien civilisation would need a transmitter 300m (984ft) wide with the power to generate 300kW of energy for us to hear a signal

NASA seeks human tissue for harmful space radiation

Scientists have been urged to grow skin to investigate the effects of being in space


In order to bag one of the three awards on offer, competing teams will need to demonstrate three successful trials with at least a 75 per cent success rate

NASA has launched a new initiative in partnership with the Methuselah Foundation's New Organ Alliance, in the hope of urging laboratories around the world to grow organic tissue for use in new space radiation studies.

The contest, called the Vascular Tissue Challenge, aims to help NASA reduce the harmful effects of deep-space exploration – there's even a $500,000 (£370,000) prize for the first three teams who successfully create thick, metabolically functional, human vascularised organ tissue in a controlled laboratory environment.

And considering the space agency is planning to eventually take manned crews to Mars and beyond, such research will be vital in testing how it can protect future astronauts from being cooked in the radioactive fires of deep space and make space travel safer.

"The humans who will be our deep space pioneers are the most important resource on our journey to Mars and beyond," says Steve Jurczyk, associate administrator for NASA's Space Technology Mission Directorate in Washington. "The outcome of this challenge has the potential to revolutionise healthcare on Earth, and could become part of an important set of tools used to minimise the negative effects of deep space on our future explorers." The study of these effects will also help further research in the field of organ transplants, so NASA is confident the programme will help introduce an influx of quality tissue.

"When the Wright Brothers discovered how to control aircraft during flight for aviation in the early 1900s, there was an explosion of progress after this key barrier was removed," adds Dave Gobel, chief executive officer of the Methuselah Foundation. "In the same way, once the 'vascularisation limit' is solved via the NASA Vascular Tissue Challenge, there inevitably will be a historic advance in progress and commercialisation of tissue engineering applications to everyone's benefit."

Scientists are still trying to discover how J1834.9 maintains a wind nebula

Magnetar's wind nebula seen for the very first time

High-energy particles have been discovered around a magnetic star

In a fascinating turn of events, astronomers at NASA have located an ultra-magnetic neutron star, known more commonly as a magnetar, surrounded by a volatile celestial phenomenon called a 'wind nebula'.

Swift J1834.9-0846 – or J1834.9 – was discovered by NASA's Swift satellite on 7 August 2011. It's also believed that this crushed and fuel-less core of a former star was a by-product of the colossal W41 supernova remnant located some 13,000 light years away.

"We don't know how J1834.9 developed and continues to maintain a wind nebula, which until now was a structure only seen around young pulsars," says lead researcher George Younes of George Washington University. "If the process here is similar, then about ten per cent of the magnetar's rotational energy loss is powering the nebula's glow, which would be the highest efficiency ever measured in such a system."

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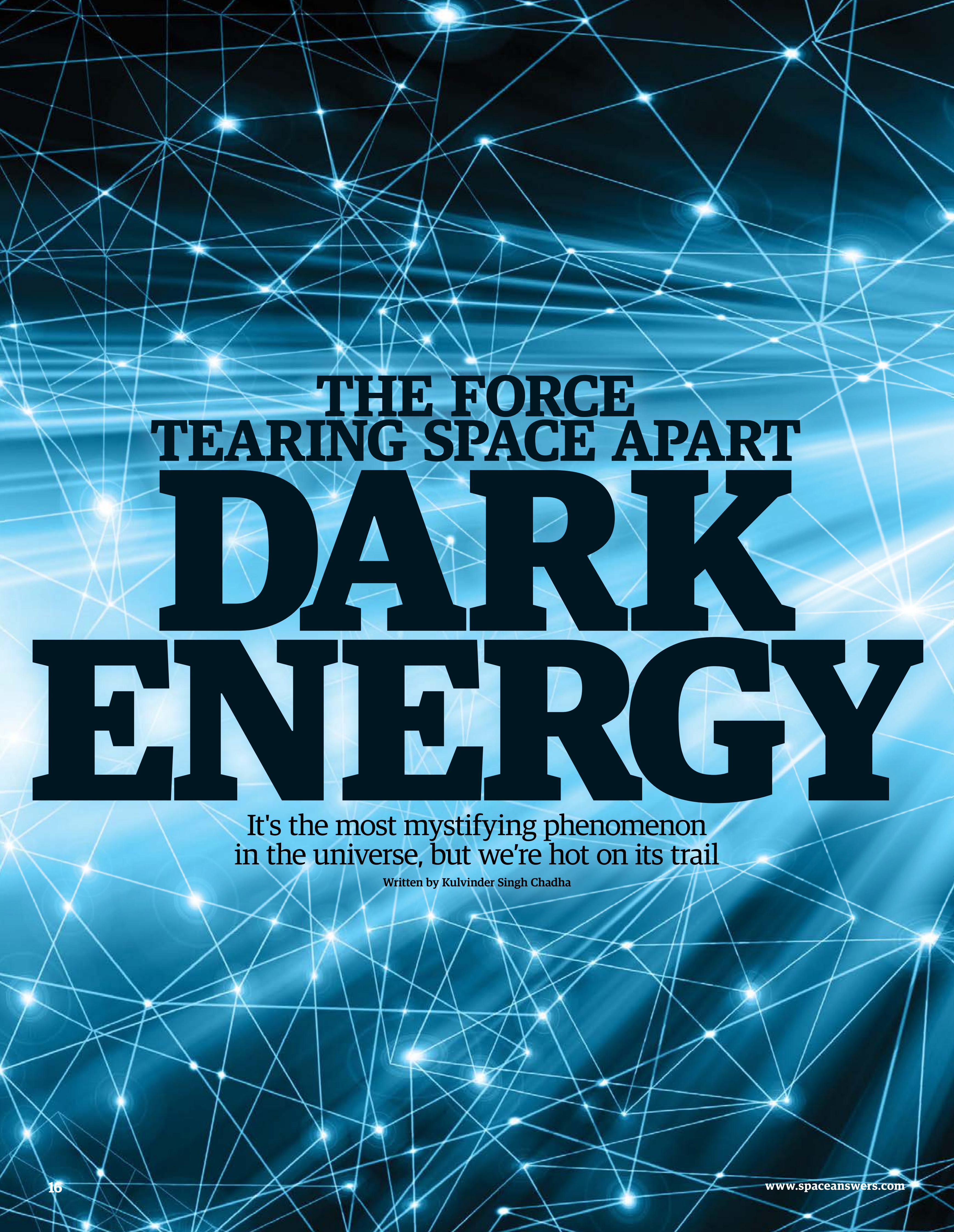


THE FORCE TEARING SPACE APART

DARK ENERGY

It's the most mystifying phenomenon in the universe, but we're hot on its trail

Written by Kulvinder Singh Chadha

© Shutterstock

RS Puppis is an example of a Cepheid variable star. These were essential in showing an expanding universe due to their luminosity-pulsation period relationship

“Dark energy was discovered by looking at the light of exploding stars in faraway galaxies”

Our universe is growing. Ever since the Big Bang, every point in the fabric of space has been expanding in all directions. This expansion is carrying almost all of the galaxies away from us. The biggest surprise, however, came in 1998 with the discovery that not only is the universe expanding, but that expansion is accelerating. Nobody knows why, but scientists have come up with a term for the mysterious force that is driving the acceleration. They call it ‘dark energy’.

According to data from the European Space Agency’s (ESA’s) Planck spacecraft, dark energy constitutes over two-thirds of all the mass and energy in the universe - that’s 68.3 per cent. (And in case you were wondering, the remainder is 26.8 per cent dark matter and just 4.9 per cent is normal matter, which makes up the stars, galaxies and planets.) Worse still, scientists are perplexed as to what dark energy actually is. There are ideas, but nothing concrete.

It is important to try and figure out the puzzle of dark energy because the fate of the universe depends on it. Prior to the discovery of dark energy, cosmologists had expected to find that the expansion of the universe should be running out of steam, 13.8 billion years after the Big Bang. If that was the case, the universe could have gone in three directions depending upon how much matter, and therefore gravity, there was in the universe.

If there was enough matter, then its gravity would act on the expanding universe, slowing the expansion and gradually overcoming it, eventually causing the universe to begin to shrink again before collapsing in a ‘Big Crunch’. If the amount of matter and gravity were finely balanced with the energy of the expanding universe, it would create a static universe that would remain forever.

What is dark energy? **All About Space** asks the astrophysicists

“Dark energy makes up about 70 per cent of the universe. It seems to be evenly spread throughout. What we have discovered about dark energy is that it ‘pushes’, as in it repels outwards. It makes the entire universe - which is already expanding - expand faster.”

Dr Karl Kruszelnicki
University of Sydney

“Dark energy is incredibly strange, but actually it makes sense to me that it went unnoticed. I have absolutely no clue what dark energy is. Dark energy appears strong enough to push the entire universe - yet its source is unknown, its location is unknown and its physics are highly speculative.”

Dr Adam Riess
Johns Hopkins University

“It could pull the universe apart. If there’s sufficient dark energy, the universe will - at some point - pull itself apart completely in a ‘Big Rip’. The only problem is that we have no clue what dark energy is.”

Dr Hitoshi Murayama
University of California, Berkeley

However, if there was not enough matter in the universe to counteract the expansion, then the universe would continue to expand forever, taking all the galaxies with it until they disappeared over the cosmic horizon, leaving the Milky Way Galaxy all alone.

With the discovery of dark energy, the fate of the universe now seems much clearer. If dark energy keeps its strength and continues accelerating the universe's expansion, then it is more likely to expand forever. In the worst-case scenario, the expansion could be so extreme that it begins to tear galaxies, stars, planets and even atoms apart. However, the trouble is, since we don't know what dark energy actually is, we cannot predict what it is going to do in the future. Astronomers can, however, measure what it is doing today and what it has done in the past, and are able to make some extrapolations based on that.

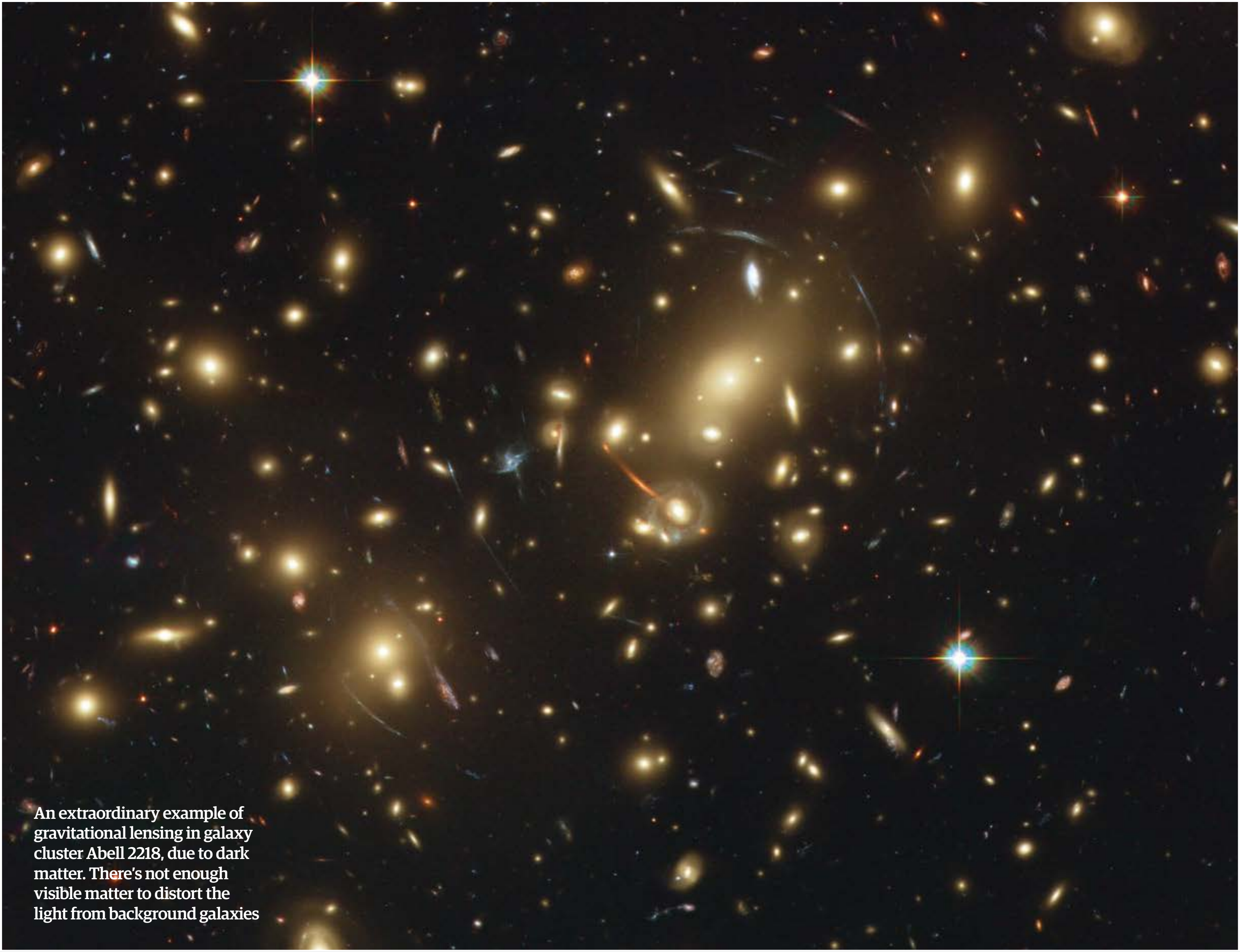
Dark energy was discovered by looking at the light of exploding stars in faraway galaxies. In particular, astronomers were looking at a particular breed of supernovae known as Type Ia. These are the explosions of white dwarf stars and they tend to all explode with the same peak brightness.

Of course, from our viewpoint, millions if not billions of light years away from these supernovae, they appear pretty faint. But because we know how bright they would be if we were up close to them, we can calculate how far away they are. Astronomers call these 'standard candles' and use them to measure distances across the universe. These distances are then compared to their cosmological redshift, which is the amount their light is stretched into redder wavelengths by the expansion of the universe.

It was the fact that the distances to these supernovae were greater than their redshift that implied that the expansion was getting faster, not slower, as identified by two teams of scientists: the Supernova Cosmology Project led by Saul Perlmutter of the Lawrence Berkeley National Laboratory, and the High-Z Supernova Search Team (Z is astronomy shorthand for redshift) led by Harvard University's Brian Schmidt and Dr Adam Riess of the Johns Hopkins University.

So supernovae continue to be used to measure dark energy. Just this year, Riess led a team of scientists who used Type Ia supernovae to discover that the expansion of the universe is even faster than previously thought. They searched for supernovae in galaxies in which they could also see a special type of variable star, called Cepheid variables. These pulsating stars are also standard candles as their maximum luminosity depends on

"Just this year, scientists discovered that the universe is expanding faster than we originally thought"



An extraordinary example of gravitational lensing in galaxy cluster Abell 2218, due to dark matter. There's not enough visible matter to distort the light from background galaxies

Dark energy vs dark matter

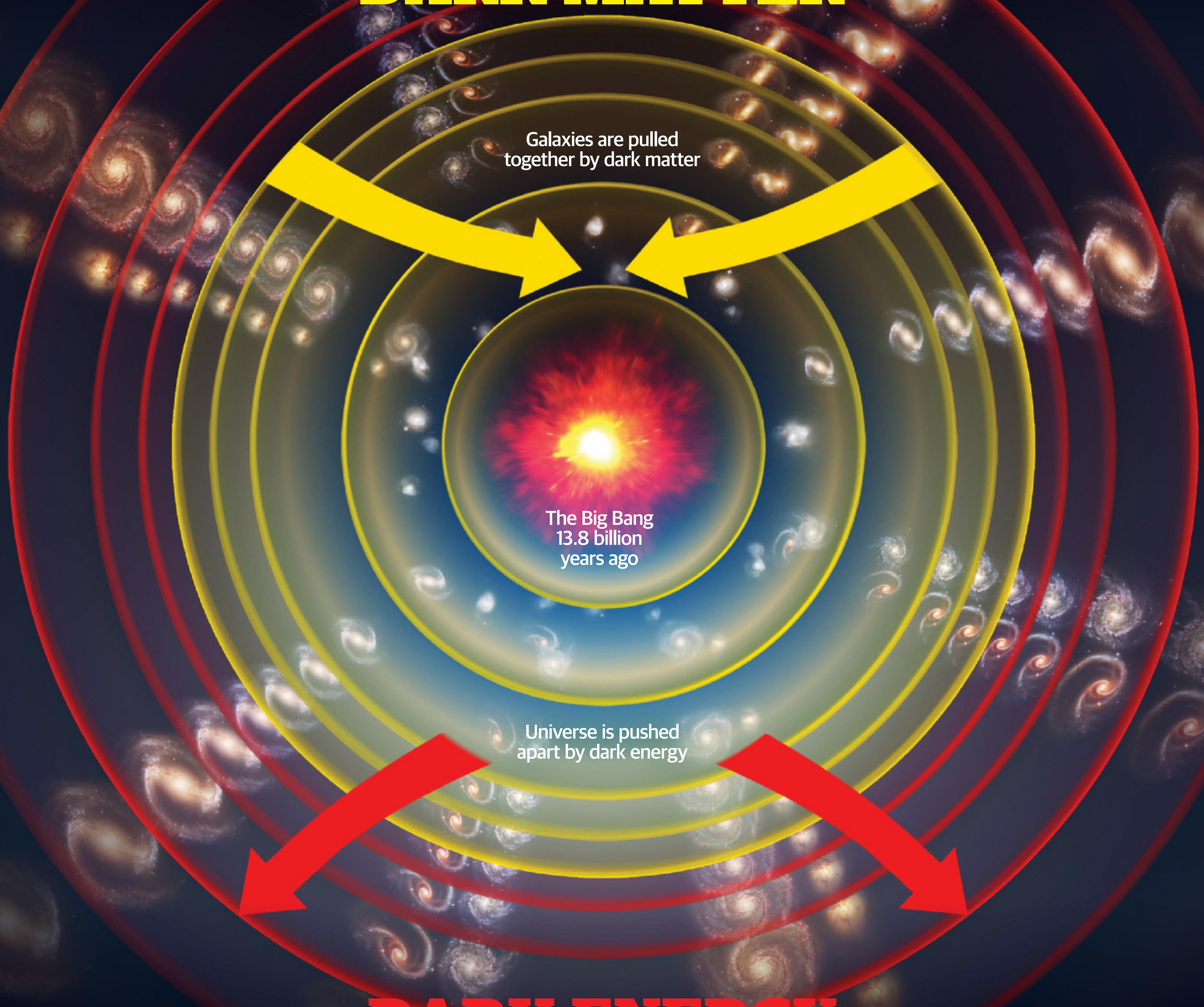
DARK MATTER

It's entirely invisible and neither emits or absorbs heat, light or radiation of any kind.

It can be detected indirectly by its gravitational effect on normal matter and space-time.

It comprises 84.54 per cent of all matter in the universe, or 26.8 per cent of the universe's total makeup

It plays a crucial role in galaxy formation and stops galaxies from flying apart.


Galaxies are pulled together by dark matter
The Big Bang 13.8 billion years ago
Universe is pushed apart by dark energy

DARK ENERGY

It is accelerating the expansion of space, shown by studies of supernovae in distant galaxies.

It exerts a small, negative pressure that's constant throughout space and acts against gravity.

It was first discovered in the late 1990s by astronomers.

It affects the shape of the universe and its large-scale structure, such as how galaxies and quasars are spread out.

© Tobias Roetsch

the length of their variation – the longer it takes for them to reach peak brightness and then fade back down to normal levels as they pulse, the brighter their peak brightness will be.

Comparing the Cepheid data with the distance of those galaxies as measured by Type Ia supernovae, Riess's team were able to calibrate the supernova distance markers, allowing them to more accurately measure the distances to even more remote galaxies. While the Planck spacecraft had measured the expansion rate of the universe as being 66.5 kilometres (41.3 miles) per second per megaparsec (a megaparsec is equal to 3.26 million light years), Riess' team found that actually the universe was expanding much faster, at 73.2 kilometres (45.5 miles) per second per megaparsec. That doesn't mean that Planck made a mistake. The rate of expansion that it measured – which is known as the Hubble 'constant' – was from the very beginning of the universe, observed in the light of the Cosmic Microwave Background radiation just 380,000 years after the Big Bang.

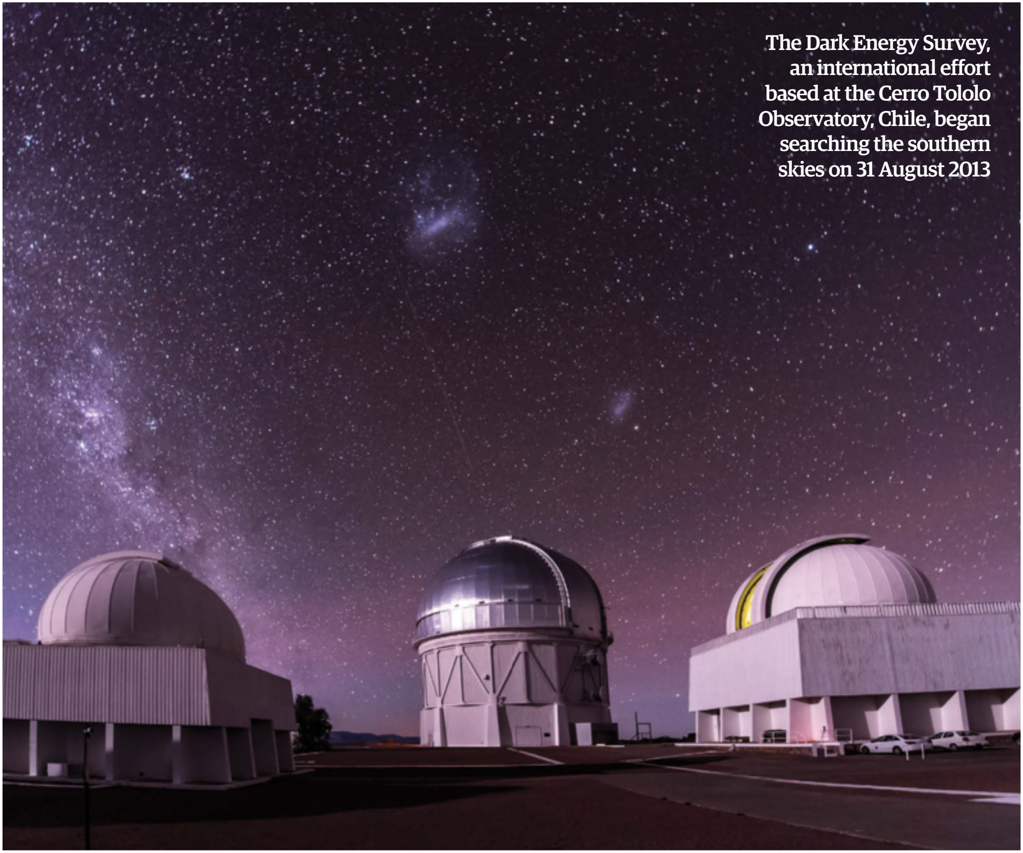
On the other hand, Riess' team measured the Hubble constant in the modern universe. It isn't clear why the two values are different, but one explanation could be that dark energy has grown stronger over the years, speeding up the expansion, meaning that the Hubble constant isn't actually constant at all. If that is true, then it has serious implications for the fate of the universe.

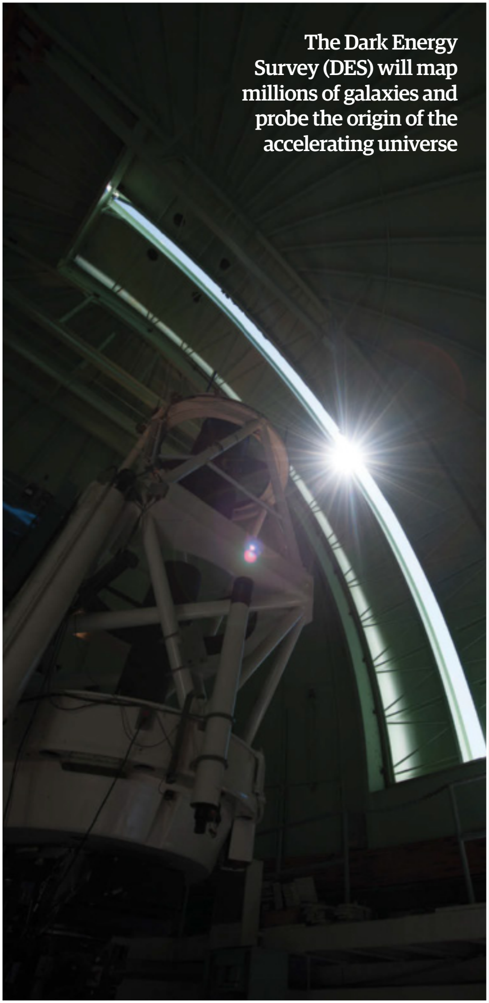
"If we know the initial amounts of stuff in the universe, such as dark energy and dark matter, and we have the physics correct, then you can go from a measurement at the time shortly after the Big Bang and use that to predict how fast the universe should be expanding today," says Riess. "However, if this discrepancy holds up, it appears we may not have the right understanding, and it changes how big the Hubble constant should be today."

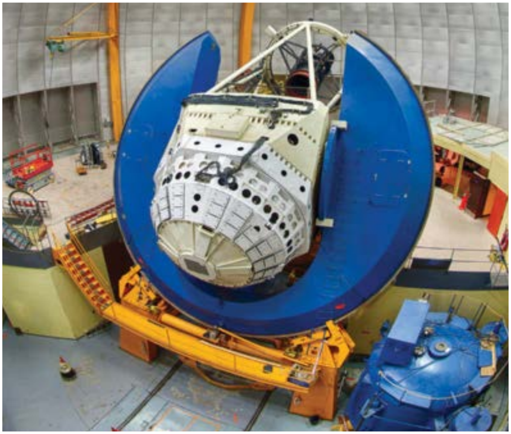
Riess' findings also somewhat contradict another recent dark energy discovery made by scientists who used NASA's Chandra X-ray Observatory to observe galaxy clusters. Because galaxy clusters are filled with gas as hot as 1 million degrees Celsius (1.8 million degrees Fahrenheit) or more, they glow brightly in X-rays. These X-ray-emitting regions of galaxy clusters all have similar shapes and sizes relative to the size of the clusters themselves.

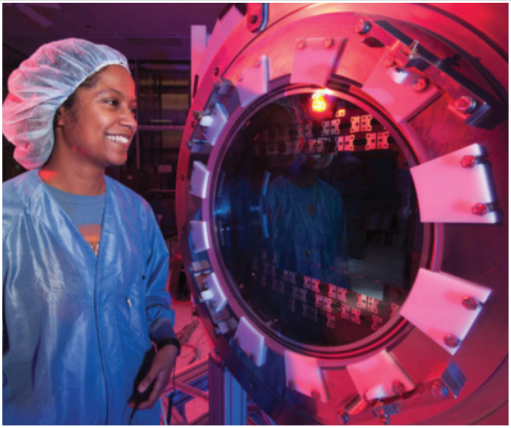
"In this sense, galaxy clusters are like Russian dolls, with smaller ones having a similar shape to the larger ones," comments Andrea Morandi of the University of Alabama, Huntsville, US, who led the team. "Knowing this lets us compare them and accurately determine their distances across billions of light years."

From these distances, the true size of the clusters can be gauged. Because the growth of galaxy clusters is ultimately stunted by dark energy pulling away galaxies that would otherwise join the clusters, how big galaxy clusters can reach during different epochs of history is an indication of how strong dark energy is and how it has acted over billions of years. Since a galaxy cluster's X-ray profile is a proxy for its true physical size, by measuring them with Chandra, Morandi's team found that dark energy doesn't seem to have become stronger or weaker in the last 8.7 billion years. This might mean that a change in the


The Dark Energy Survey, an international effort based at the Cerro Tololo Observatory, Chile, began searching the southern skies on 31 August 2013


The Dark Energy Survey (DES) will map millions of galaxies and probe the origin of the accelerating universe


DES will carry out a deep, wide-area survey over 525 nights to record information from 300mn galaxies


More than 400 scientists from over 25 institutions across the world are working on the DES project

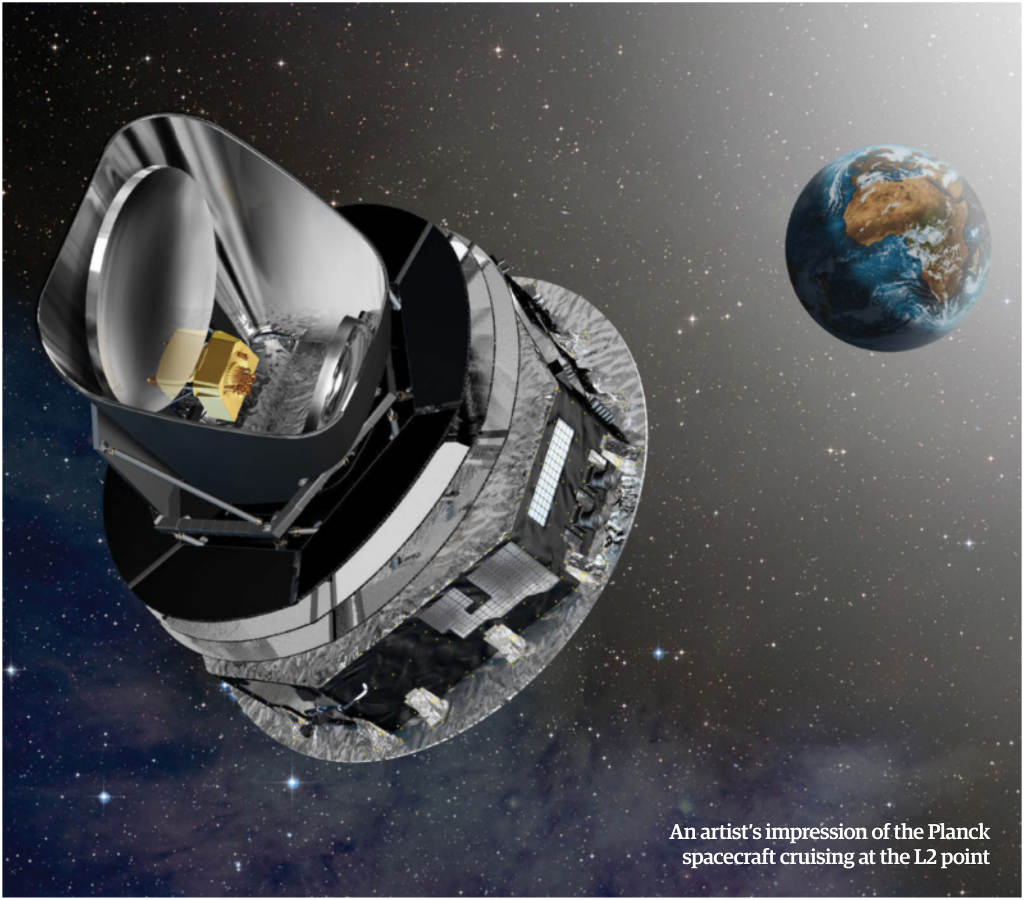
expansion rate of the universe occurred before then, closer to the time of the Big Bang.

Galaxies can also reveal the presence of dark energy in other ways. We've seen standard candles in the form of supernovae, so now meet 'standard rulers', which are physical yardsticks that we can measure dark energy against. The distribution of galaxies in the universe can be traced back to perturbations seen in the cosmic microwave background, which resulted in a standard distance between galaxies. This standard distance can act like a ruler and, by measuring how the distance between galaxies has grown as the universe has expanded, astronomers can measure the strength of dark energy.

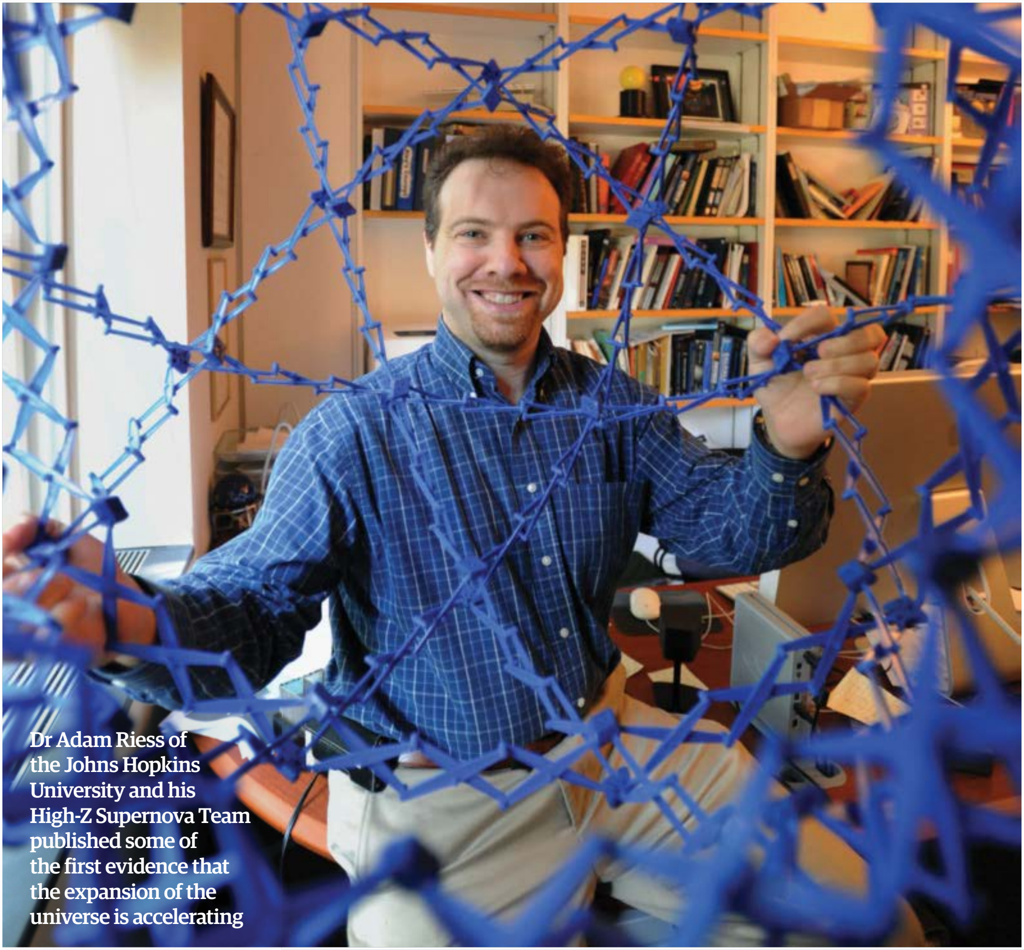
However, for standard candles and standard rulers to really make a difference in our quest to solve the mystery of dark energy, what scientists really need is much more data. This data will come from giant galaxy surveys, conducted by both general-purpose observatories and dedicated dark energy projects. First up is the Dark Energy Survey, which is an international project to detect many thousands of Type Ia supernovae, but which also aims to map out the large scale structure of the universe in the form of hundreds of millions of galaxies, providing many more examples of standard rulers.

The Dark Energy Survey began in 2013 and it uses the four-metre (13-foot) Blanco telescope and its powerful 570-megapixel Dark Energy Camera at the Cerro Tololo Inter-American Observatory, situated in Chile. The project released its first batch of data for scientists to begin analysing in January 2016, and the survey will continue to run until 2018.

"Thanks to the extreme sensitivity of the camera and to the large area of sky that can be imaged through the telescope at once - 15 times the size of the full Moon - we expect the Dark Energy Survey to find more supernovae than any previous experiment," comments Dr Chris D'Andrea of the University of Portsmouth, UK. In the first few months alone, it found 200 Type Ia supernovae. However, we're still a few years away from having a thorough analysis of the results. Meanwhile, there will be an American rival to the Dark Energy



An artist's impression of the Planck spacecraft cruising at the L2 point



Dr Adam Riess of the Johns Hopkins University and his High-Z Supernova Team published some of the first evidence that the expansion of the universe is accelerating

> "Dark energy appears strong enough to push the entire universe – yet its source is unknown, its location is unknown and its physics are highly speculative"
>
> **Dr Adam Riess**

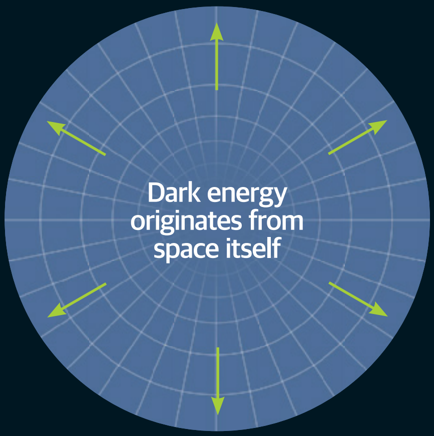
Dark energy and the future of the universe

There are several possible scenarios for the fate of the cosmos, but only time will tell which will prevail - and dark force is partly responsible

SCENARIO 1 Expanding forever: *dark energy is the same everywhere*

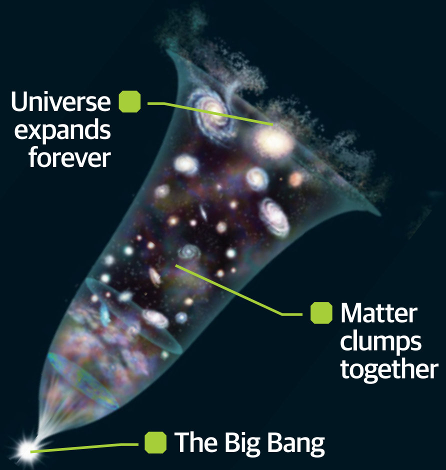
NOW

In this scenario, there's not enough gravitation to stop or slow the expansion of space. In an ever-expanding cosmos, dark energy has the same strength everywhere.



FUTURE

The universe continues to expand as it has been doing so; accelerating, but not so much that anything drastic happens. Stars and galaxies continue to evolve indefinitely and for an infinite amount of time.

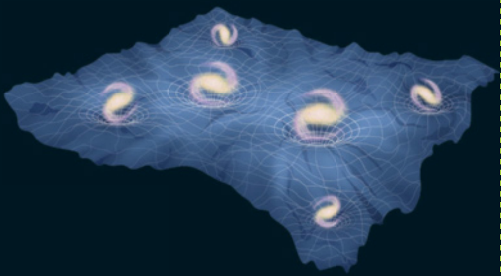


SCENARIO 2 Big Crunch or Big Rip: *dark energy alters its strength*

NOW

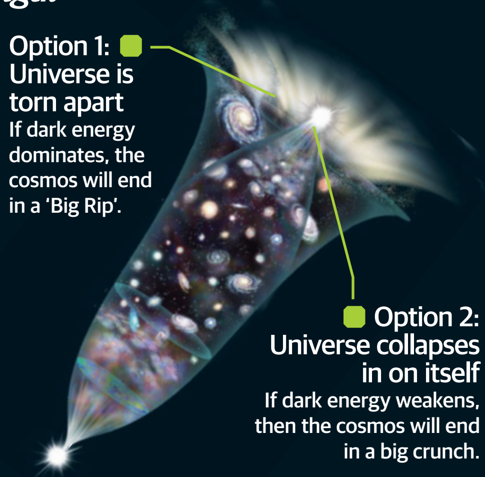
Many cosmologists think that dark energy could have different strengths in different parts of the universe. Having a varying 'concentrate' of this strange force means that there's a continual of repulsion, even when the cosmos is expanding. A change in dark energy's strength could explain how large galaxy clusters are made.

Dark energy's strength changes as the universe expands



FUTURE

Variable dark energy leads to two possibilities: it continues to dominate, leading to ever-faster expansion where galaxies, stars and planets are torn apart in a 'Big Rip', or dark energy weakens, causing gravity to dominate. Eventually the expansion of the universe slows so much that the cosmos ends in a 'Big Crunch'.


Option 1: Universe is torn apart
Option 2: Universe collapses in on itself

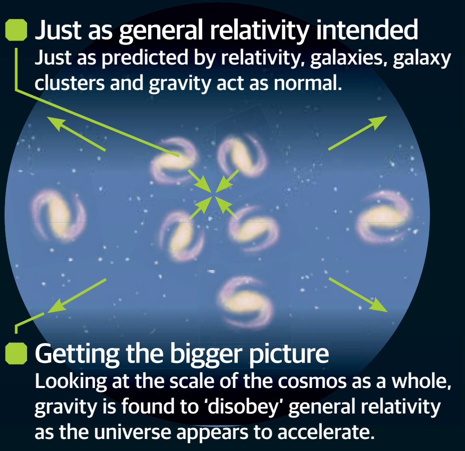
If dark energy dominates, the cosmos will end in a 'Big Rip'.

If dark energy weakens, then the cosmos will end in a big crunch.

SCENARIO 3 An illusion: *dark energy isn't real*

NOW

The final scenario is that dark energy doesn't exist in the way we think and that it is in fact a huge illusion. Modifications of general relativity can explain distant supernovae and galactic redshift observations without the need for dark energy, suggesting a fundamental flaw in our understanding of gravity.



Just as general relativity intended
Just as predicted by relativity, galaxies, galaxy clusters and gravity act as normal.

Getting the bigger picture
Looking at the scale of the cosmos as a whole, gravity is found to 'disobey' general relativity as the universe appears to accelerate.

FUTURE

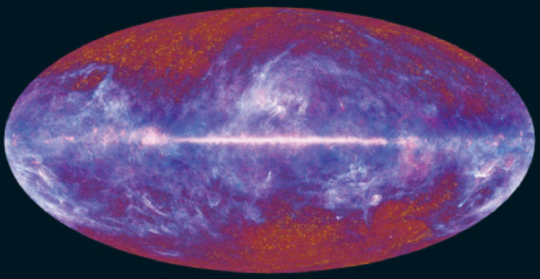
In the case where dark energy or the cosmological constant doesn't exist, we may need to re-evaluate how gravity works on different scales. On galactic scales it may be attractive and may act like dark matter, but on larger scales it may continue to cause expansion.

An uncertain future
Until we understand fully how gravity behaves on large scales, the future of the cosmos is anyone's guess.

The evidence for dark energy

1 The relic radiation that fills space

The cosmic microwave background (CMB) is the distant, primordial microwave 'echo' of the universe. Measurements of the CMB taken by space probes show that the universe's geometry is nearly flat. For that to be the case, the total amount of matter in space must tally with the average density of matter to energy in the cosmos. But measurements of the CMB spectrum show that this isn't what's happening - matter only accounts for 30 per cent of the density. Something is missing.



2 Exploding stars

A Type Ia supernova occurs in binary systems when a white dwarf's gravity pulls material from the other orbiting star onto itself, causing it to explode, briefly outshining all other stars in its galaxy. This means they are visible across the cosmos. Their intrinsic brightness is also known, so their distances can be calculated from how dim they appear. Using this method, scientists were able to show that the universe's expansion is accelerating.

3 The shape of the cosmos

The shape of the universe is governed by the general theory of relativity, which describes how space-time is warped by matter. Measurements of the CMB radiation show that the universe is nearly flat, except that there's not enough matter to keep it that way. Since $E=mc^2$ shows that matter and energy are two sides of the same coin, could dark energy remedy the shortfall as the intrinsic energy of space?

4 The universe is expanding

The expansion rate of the universe is the time it takes to expand a certain amount. In a certain period of time, space will expand by a certain amount and whatever makes space expand doesn't dilute or decrease in density. An expanding universe leads to a greater amount of space, and more of what caused the expansion. This suggests that dark energy may be a feature of space itself.

Survey, named the Dark Energy Spectroscopic Instrument, or DESI for short. It's destined for the four-metre (13-foot) Mayall telescope at the Kitt Peak National Observatory in Arizona, and will measure the cosmological redshifts of 30 million galaxies out to a distance of 10 billion light years in order to create a huge map of the large-scale structure in the universe. It will look at how the expansion of the universe has stretched the space between individual galaxies, as well as the size of galaxy clusters.

Unfortunately, it doesn't start work until 2018, just as the Dark Energy Survey is completing its work, so we will have to wait a while for its results, but it will build on the efforts of previous surveys such as BOSS, the Baryon Oscillation Spectroscopic Survey, which was part of the Sloan Digital Sky Survey based in New Mexico. This measured the redshifts of a million galaxies across 6 billion light years and allowed comparisons to be made of the growth of standard rulers between the modern day and 6 billion years ago.

It's an even longer time frame for other projects. The most powerful digital camera in the world, featuring 3.2 billion pixels, will be fitted to the heart of the Large Synoptic Survey Telescope (LSST) - a huge 8.4-metre (27.6-foot) telescope that is under construction on a mountain called Cerro Pachon in Chile. While it will be a general-purpose survey telescope, the LSST will map millions of galaxies and find many more supernovae to aid in the quest to learn more about dark energy.

But there are more ways to study dark energy than just with visible light. The Square Kilometre Array, a vast interconnected network of thousands of small radio telescopes that will come online in the next decade, will study dark energy in two ways. First, it will listen for how the gravity of galaxy clusters affects the passage of radio waves through the universe, with the size of the radio distortion being a signal to indicate the different size of standard rulers across billions of years.

It will also complete a survey of galaxies via the 21-centimetre (8.3-inch) wavelength radio emissions from neutral hydrogen in those galaxies, adding to the many galaxies observed by other surveys to help create a comprehensive map of the universe from which we will be able to measure dark energy across space and time.

Finally, the quest for dark energy will be quite literally heading into space with the joint ESA/NASA Euclid mission, which is set to launch in 2020. Armed with a 1.2-metre (3.9-foot) telescope, which is a decent size for a space mission, and a 600-megapixel digital camera, it will map the size and location of a whopping 2 billion galaxies, more than have ever been mapped before, across 10 billion light years. It will tell the story of the evolution of the standard rulers in the universe, as well as highlight the result of the battles between gravity and dark energy in the growth of galaxy clusters.

"Euclid will provide a wealth of data on the three-dimensional matter distribution in the universe," says Ralf Bender of the Max Planck Institute for Extraterrestrial Physics in Germany, who is a scientist working on the Euclid mission. "Not only will this give us interesting insights into the evolution of galaxies and galaxy clusters, but we will also be able to better understand the accelerating expansion of the universe. Hopefully, this will bring us a big step forward in solving the riddle that is dark energy."

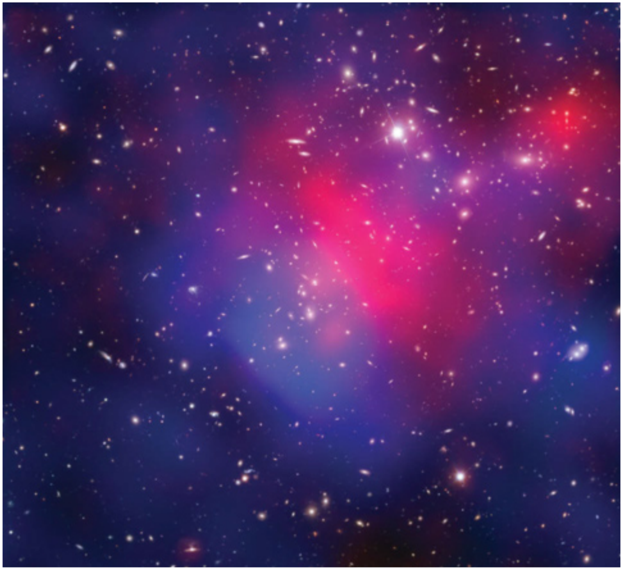
Of course, the solution to that riddle is the 64 million dollar question. Although nobody knows exactly what dark energy is, scientists' best guess is that it is one of two types of phenomenon. The first idea is that it is something called quintessence, which is a type of energy field that varies across space-time. Adam Riess' measurement of a modern-day expansion rate of the universe, that is at odds with the expansion rate not long after the Big Bang, may be evidence that the quintessence model is the correct one.

On the other hand, an alternative model is described as the Cosmological Constant, which is a constant energy field that has the same strength at all points in space and time. If dark energy is the Cosmological Constant, it would mean that either Riess' measurement of the expansion, or Planck's data, is somehow in error or being misinterpreted. Quintessence and the Cosmological Constant are fairly vague descriptions, however.

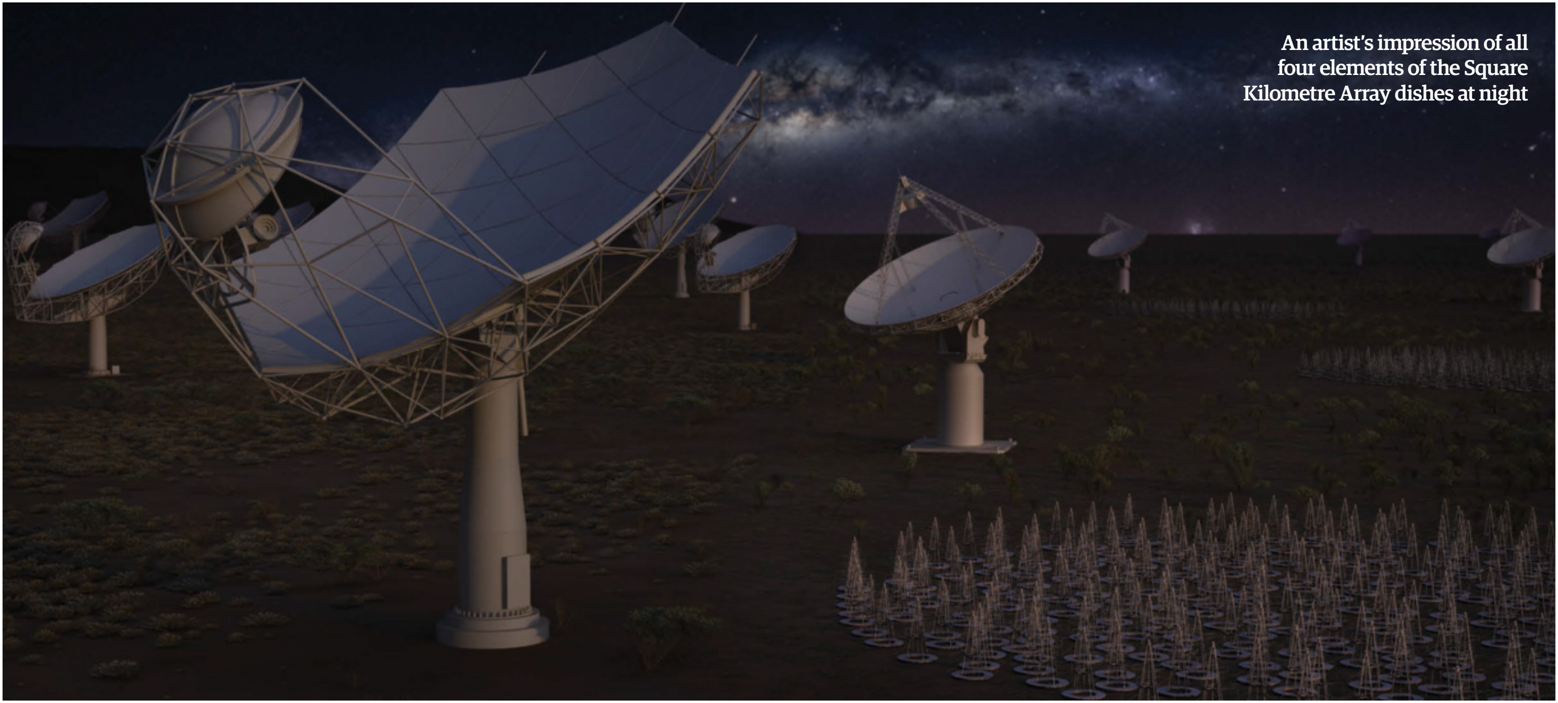
What exactly dark energy is, how it arises, and where this mysterious force gains its strength from are still open questions, but for scientists working to figure it out, there's a big prize awaiting them. Riess, Schmidt and Perlmutter won the Nobel Prize for Physics just for discovering dark energy. The scientists that finally solve the mystery won't just win the Nobel Prize - they could well be the first scientists to conclusively declare what the fate of the universe will be.

> "Dark energy has grown stronger over the years, speeding up the expansion, meaning that the Hubble constant isn't actually constant at all"

Various instruments, such as DASI (pictured here), helped corroborate WMAP's findings that our universe is nearly flat



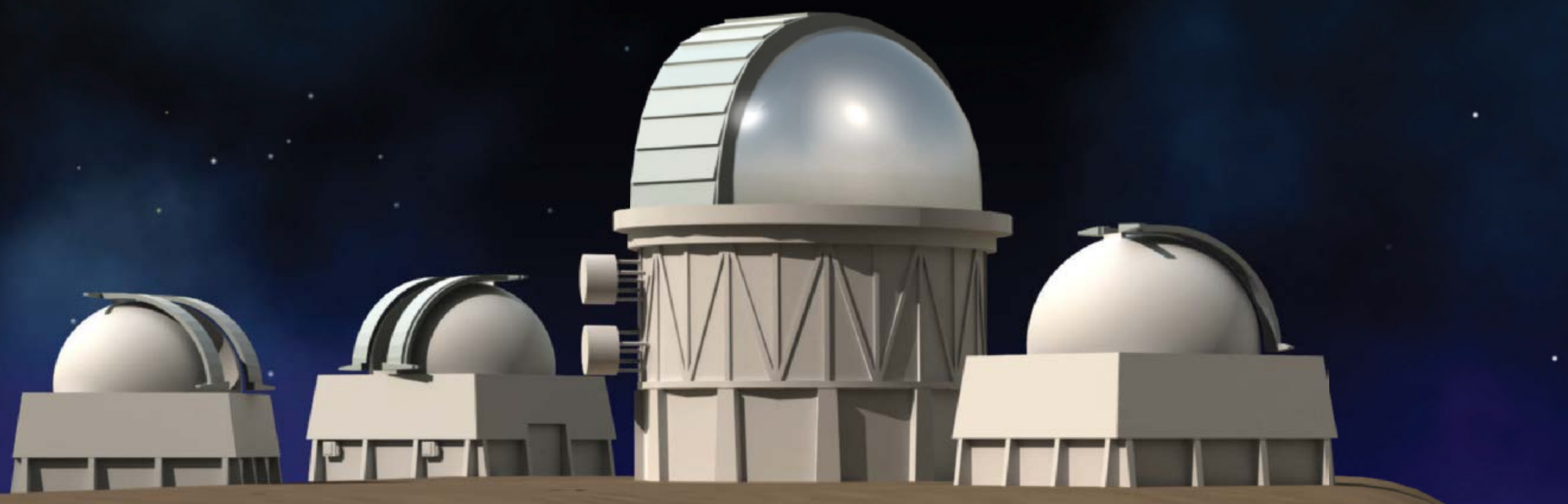
An image of a galaxy cluster, with hot intracluster gas shown in pink. The blue overlay reveals the calculated areas of dark matter



An artist's impression of all four elements of the Square Kilometre Array dishes at night

Dark energy mappers

A new generation of instruments promises to hunt down dark energy, exposing its darkest secrets



Dark Energy Survey (DES)

This is a visible and near-infrared survey of the universe using the four-metre (13-foot) Blanco telescope at the Cerro Tololo Inter-American Observatory in Chile. The telescope has been fitted with the state-of-the-art, robotic Dark Energy Camera (DECam), which will survey 300 million extremely faint galaxies and thousands of supernovae over an eighth of the total sky. The DECam instrument will make repeated observations of certain areas of the sky in various wavelengths, as well as more long-period observations to pick out the faintest galaxies. In this way, the DES project hopes to discover if dark energy's density changes over time.

400
Individual scientists from the US, Spain, the UK, Brazil, Germany, Switzerland and Australia are working on DES

520
The total number of megapixels in DECam's sensor
Equivalent to: **43 smartphone cameras**

176kg
The weight of the largest of DECam's five lenses

-100
The temperature, in degrees Celsius, to which DECam's 74 CCDs must be cooled

300 million
The number of faint galaxies that the survey will record using the Dark Energy Camera

21
The wavelength, in centimetres, of the hydrogen radio emissions that SKA will observe

100
The multiple of today's entire internet traffic that SKA's aperture arrays could produce

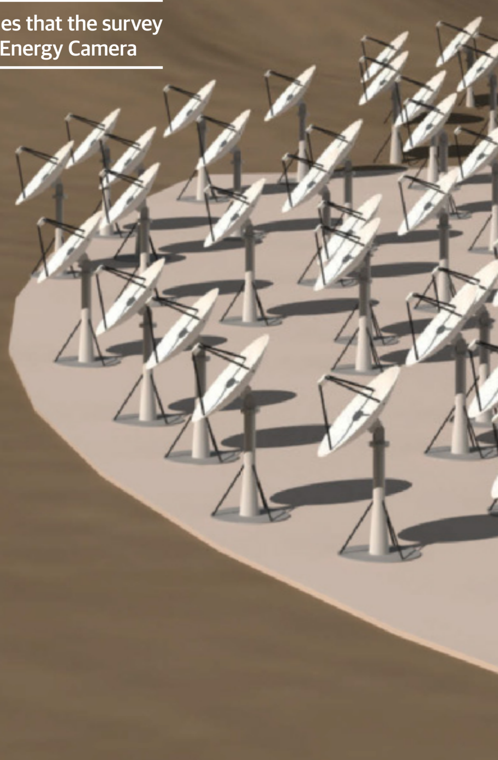
1 million
The approximate number of antennae in the SKA network

8.4 million
The number of today's latest smartphones that SKA's data would fill in a single day

SKA's total collecting area in square kilometres
over 4 tennis courts

Square Kilometre Array

The Square Kilometre Array (SKA) will span two continents when it begins operation in 2020. As the largest radio telescope network in history, all of SKA's individual elements will be able to act like a single, super-continental radio dish, giving it the ability to study the universe in resolutions never before seen in radio wavelengths. In particular, emissions from hydrogen gas - the most abundant element in space - will be mapped in three dimensions from the distant past to the present day. SKA's high resolving power could reveal dark energy's effects from ripples in the gas and more information on galactic evolution.



Euclid space telescope

How has dark energy contributed to the universe's acceleration over cosmic time? This is what ESA's Euclid spacecraft will try to ascertain when it is launched in 2020. It will do this by measuring the redshifts of galaxies back to when the universe was just 28 per cent of its current age. It will also look at gravitational weak lensing, as well as ripples in normal matter (usually in hydrogen gas between galaxies). To get decent results, Euclid will survey at least half the entire sky with its visible and near-infrared cameras.

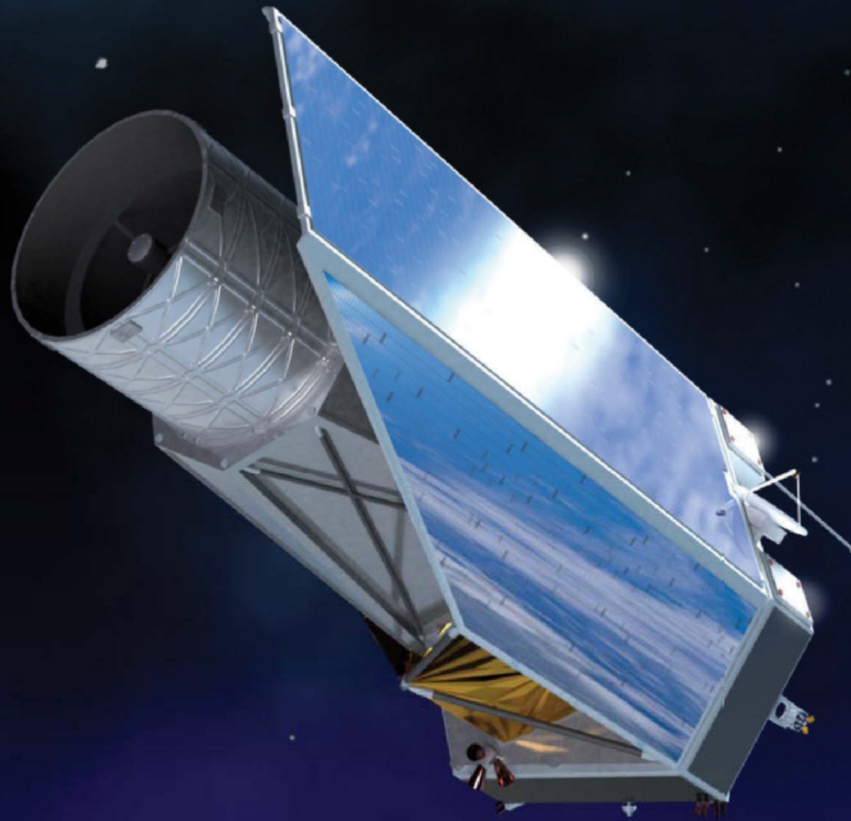
0.36 The total area of the sky that Euclid will observe during its 6.5-year mission life

850 The number of gigabits of compressed data that Euclid will collect per day

10 billion The number of years into the universe's past that Euclid will look into

1.2 Diameter of Euclid's Korsch telescope mirror, in metres

1.5 million Euclid's distance, in kilometres, from Earth in its operational orbit



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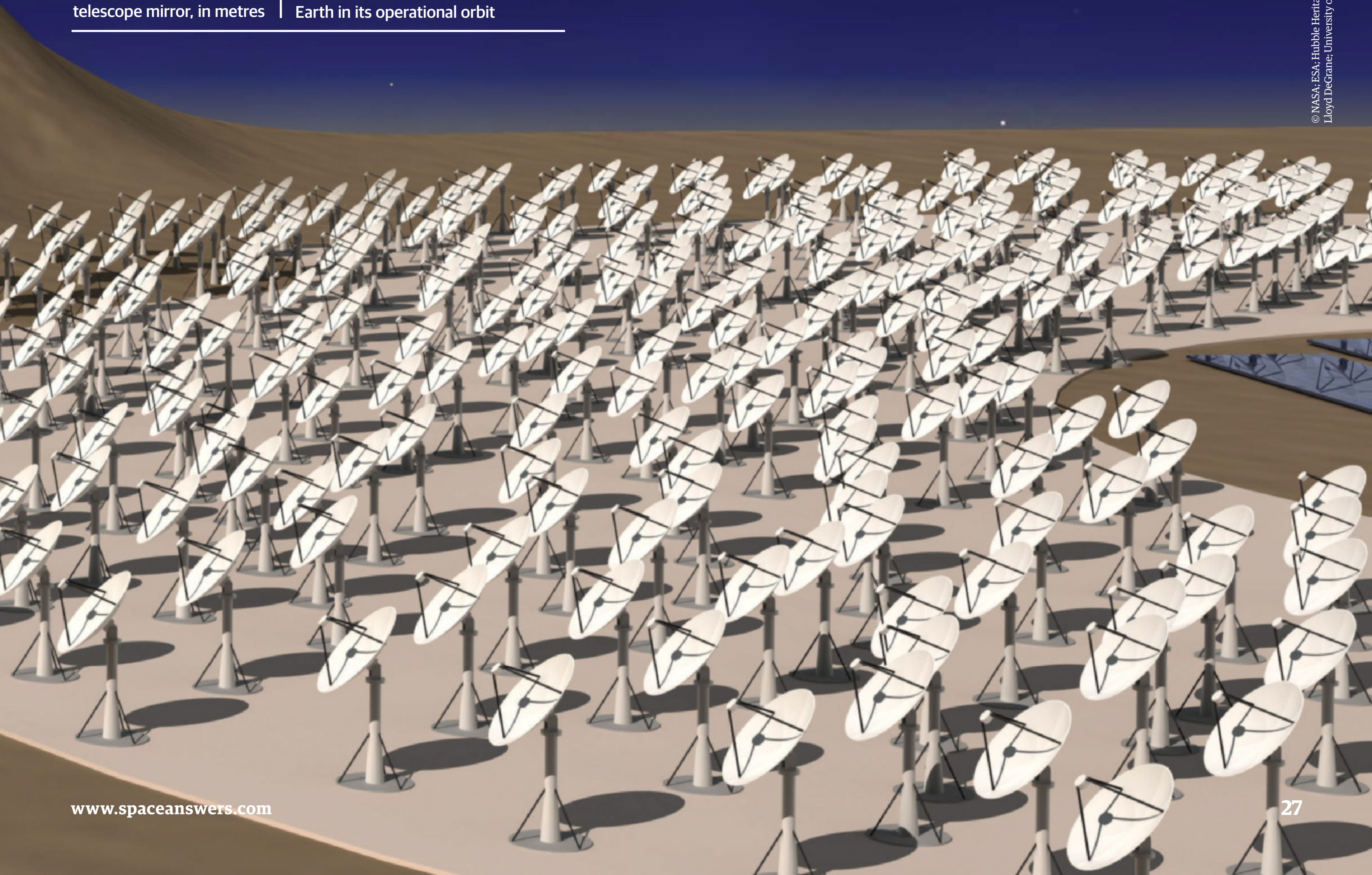

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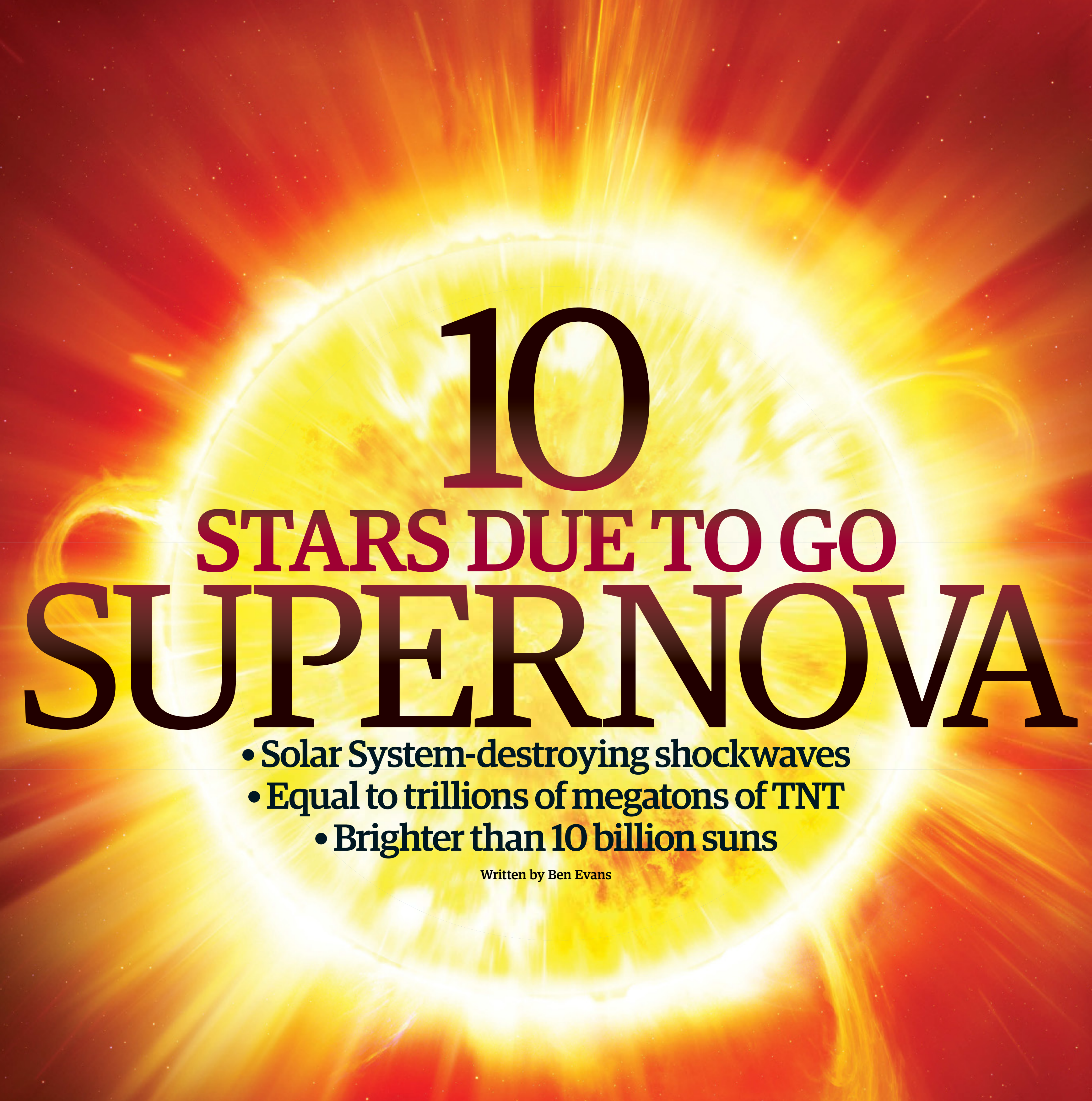

10

STARS DUE TO GO SUPERNOVA

- Solar System-destroying shockwaves
- Equal to trillions of megatons of TNT
- Brighter than 10 billion suns

Written by Ben Evans

Since ancient times, supernovae - the explosive deaths of old stars - have been observed and recorded with fascination by humans here on Earth. Chinese astronomers described an event in 185 CE as resembling a large bamboo mat in the sky and noted that its five colours were "both pleasing and otherwise". Almost a thousand years later in 1006, Islamic scholars witnessed a "spectacle" three times the apparent size and 16 times the brightness of Venus, which may also have been recorded in Native American petroglyphs.

Then, in 1604, the German astronomer Johannes Kepler directly observed the most recent supernova to have originated within our own galaxy, the Milky Way. It originated 20,000 light years away and was so bright that it could be seen during the daytime for three weeks.

Within our own galaxy, only five supernovae have been observed with the naked eye in the last millennium. Others have been recorded telescopically - including Supernova 1987A in the Large Magellanic Cloud - and it has been estimated that about one or two of these events occur in any single century. Yet the vast distances between the stars, and the immense amount of time required for their light to reach us, mean that in most cases we are only able to see the stars as they were hundreds or even thousands of years ago.

Although we know which stars have almost exhausted their nuclear fuel reserves and are approaching the end of their lifetimes, we can only surmise when they will 'go supernova'. Ten candidates of varying ages and sizes are known to be close to death. They may have already exploded and the light from their agonised death-throes may still be hurtling across the universe at 300,000 kilometres (186,000 miles) per second to someday reach us. We may not see a supernova in our lifetime; or we could see one tomorrow.

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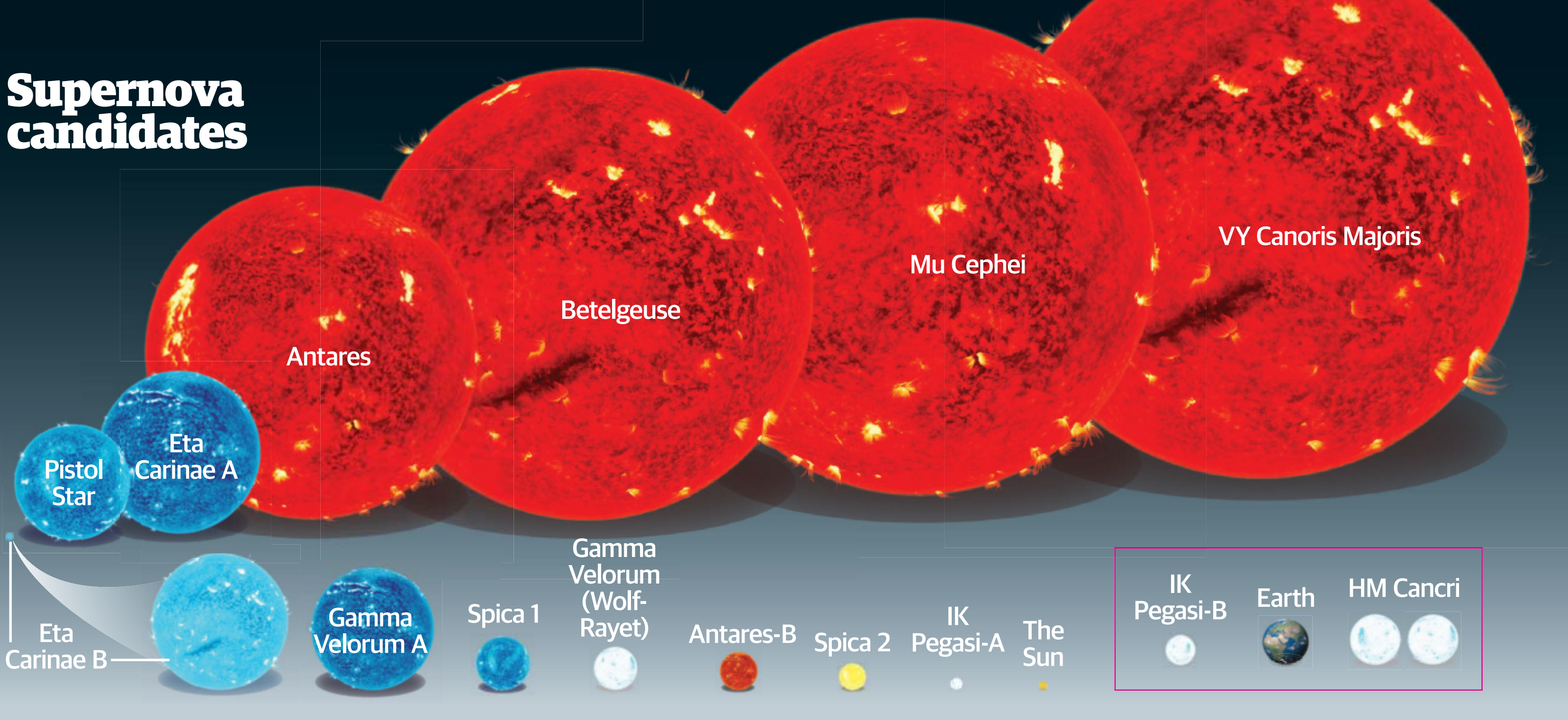
Supernova candidates



This pair of dense white dwarfs orbit each other every 321 seconds and are the fastest moving binary system ever found

1 HM Cancri

Making ripples in the fabric of space-time

Several hundred thousand years

Over 16,000 light years away, a pair of dense 'white dwarfs' - tiny stellar remnants, with masses equivalent to that of the Sun, bundled into diameters broadly the size of Earth - circle each other every 321 seconds.

In doing so, they are the fastest-moving binary system ever found. Separated by 80,467 kilometres (50,000 miles), a fifth of the distance between Earth and the Moon, the half-solar-mass X-ray binaries of HM Cancri whirl around one another at 1.4 million kilometres (890,000 miles) per hour. As each day passes, their orbit brings them closer, raising the probability that they will eventually merge.

When they do merge, it is likely that HM Cancri will produce a Type Ia supernova. The latter occurs in binary systems with one or more white dwarfs, which, although little more than the 'corpses' of deceased stars, remain capable of further fusion reactions and can still pack an energy-laden punch if their temperatures rise high enough. In fact, the HM Cancri duo, containing highly condensed helium, carbon and oxygen, are so close together that mass flows from one to the other.

First identified as a weak X-ray emitter by German's ROSAT craft in 1999, HM Cancri may also be one of the strongest sources of gravitational waves ever observed.

Both the red supergiant Antares and its bluish-green companion, Antares-B, vastly outshine our Sun

2 Antares

Mars' rival

Within a few hundred thousand years

When Antares reaches the end of its life, it could be as bright as a full Moon and perhaps visible on Earth for several months. At 883 solar radii, it is smaller than Betelgeuse but has a similar surface temperature and mass. Antares is at the heart of the constellation Scorpius and is around 12 million years old. It will likely go supernova in a few hundred thousand years.

Named by the Ancient Greeks for its similar colour to Mars, 'Antares' means the rival of Mars, using 'Ares', the Hellenic name for the Roman god of war. Located around 550 light years from Earth, Antares is joined by a smaller and dimmer companion, Antares-B. Both, however, greatly outshine the Sun. The end of Antares could have already begun, or it may take the next few hundred millennia for it to go supernova.

3 Gamma Velorum

An explosion of multiple stars

Perhaps a few thousand years

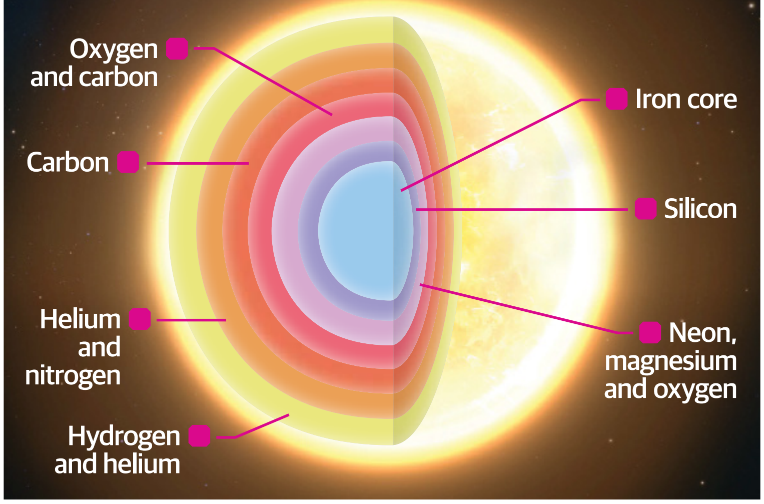
As the brightest object in the constellation of Vela, Gamma Velorum is not one star, but at least four or even six. Alternatively known by its Arabic name of 'Suhail' or as 'Regor', in honour of Apollo 1 astronaut Roger Chaffee, its brightest members are the binary pairing of Gamma Velorum A.

Situated around 336 light years from us, this duo comprises of a blue supergiant and the nearest-known example of a 'Wolf-Rayet' star. Wolf-Rayet stars are characterised by high stellar winds and extreme surface temperatures and tend to lose mass quickly, usually within a million years or so.

In Gamma Velorum A's case, the Wolf-Rayet star may have already stripped itself down from 40 solar masses to its present state of nine solar masses. Although it is probably no older than 5.5 million years old, it is at an advanced state of age and is expected to meet its end as a Type Ib or Ic supernova.

Sometimes described as 'stripped core-collapse supernovae', these events are believed to occur when the star has burned its way through all of its nuclear fuel reserves, generated an iron core and has gravitationally collapsed.

Inside a Wolf-Rayet star



4 Pistol Star

The mysterious supernova

Perhaps 1-3 million years

Hidden from view by a cloak of interstellar dust, the Pistol Star is one of the most mysterious objects upon which a supernova may soon creep. Observed by Hubble in the 1990s, this highly luminous blue hypergiant is 25,000 light years from Earth, close to the Milky Way's centre. It was claimed to be 10 million-times brighter than our Sun, but this has since been adjusted to 1.6 million-times. It remains impressive, however, that in just 20 seconds the Pistol Star radiates as much energy as our Sun does in an entire year.

At the time of its birth, it is thought to have already attained somewhere around 200 solar masses, although much of this was lost in a sequence of violent eruptions. These ejected upwards of ten solar masses of expanding gaseous material in a pair of titanic outbursts, some 4,000 and 6,000 years ago. With a current radius over 300 times that of the Sun, the Pistol Star is currently thought to be about 27.5 times as massive.

It will continue to lose material until its core is exposed. By burning a figurative candlestick at both ends - its surface temperature is 11,526 degrees Celsius (20,778 degrees Fahrenheit) - the Pistol Star will meet a rapid, fiery end in a supernova within 3 million years. Alternatively, it might end its days as a super-luminous 'hypernova', which could serve as the progenitor of long-duration gamma-ray bursts.

5 Eta Carinae

The repeat detonator

A few hundred thousand years

Despite early claims that the Pistol Star was the most luminous star ever found, it's actually three-times dimmer than the luminous blue variable star, Eta Carinae. The latter was originally recorded at fourth-magnitude, but in a 20-year event called the 'Great Eruption' it dramatically blazed to become the brightest star in the sky. It subsequently dimmed, brightened, dimmed and then increased in luminosity again from the 1940s. Today, it sits at magnitude 4.5.

This changeable luminosity was triggered by Eta Carinae's ejection of the Homunculus Nebula, a cloud of ionised hydrogen whose light reached Earth in 1841. Condensation of dust from the nebula is thought to have been responsible for this cyclic brightening and dimming. That said, Eta Carinae is 5 million times more luminous than our Sun. Until recently, it was believed to be one of the most massive stars, but in 2005 it was found that it was actually a binary system.

Its primary may have reached 150 to 250 solar masses in its youth, but has sustained one of the highest rates of mass-loss ever recorded for a star. Eta Carinae's extreme luminosity and low gravity seem to have caused this loss and it is believed that it shed ten to 20 solar masses in the Great Eruption. Its primary could go supernova tomorrow, or thousands of years from tomorrow.

6 IK Pegasi

The double star

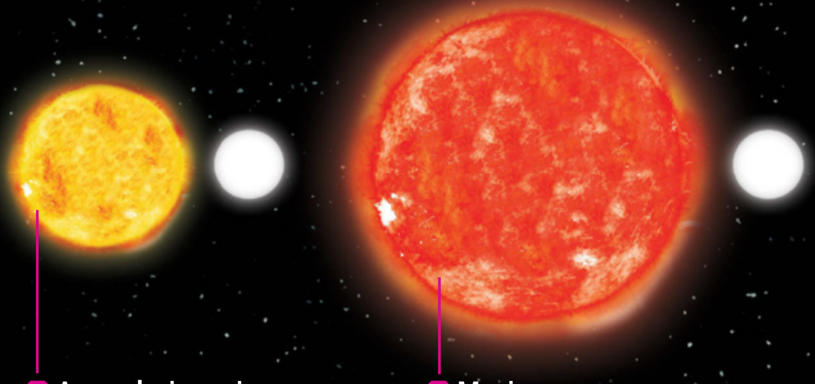
Within tens of millions of years

Perhaps the closest candidate for a supernova explosion, IK Pegasi is a binary system that resides about 150 light years from our Sun.

IK Pegasi-A is a main-sequence star that undergoes rapid pulsations in luminosity, which are triggered as its outer atmosphere optically thickens in response to the partial ionisation of elements. Temperatures rise, causing the atmosphere to expand and when ionisation decreases, it contracts.

Its companion, IK Pegasi-B - from which it is separated by 30.5 million kilometres (19 million miles) - is a massive white dwarf. When IK Pegasi-A moves off the main sequence and expands in later life to become a red giant, its companion may begin to siphon material from its surface and grow in solar mass. But IK Pegasi-A is still barely 1.7 solar masses and has a long way to go before it reaches the eight-solar-mass minimum needed to go supernova, known as the Chandrasekhar Limit. As for IK Pegasi-B, it is currently a large white dwarf and stands at 1.15 solar masses.

How IK Pegasi will explode



An explosive pair
The IK Pegasi system consists of a main-sequence star and a massive white dwarf

Moving on
IK Pegasi-A moves off the main sequence and becomes a red giant.

Betelgeuse is the largest known star to humanity and is under 10mn years old

7 Betelgeuse

The explosion visible from Earth

Any time within the next million years

Famed for its size, changeable magnitude, pulsating shape and a mispronounced name, the red supergiant Betelgeuse may have already gone supernova. It lies 640 light years away, so we won't know about it for centuries, but to our descendents it will greatly outshine the Moon in the night sky and will remain visible for months, before gradually fading away.

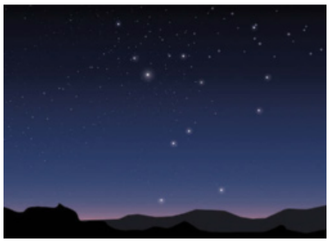
It forms the right shoulder of the constellation Orion and is under 10 million years old; it's a toddler in stellar terms. But the cool, slow-rotating Betelgeuse started life at 15 to 20 solar masses and evolved rapidly.

Hundreds of times younger and larger than the Sun, it has probably already exhausted the hydrogen in its core and in 2014 it was suggested that it might be consuming its carbon and oxygen reserves. It will then burn higher elements and could explode within 100,000 years, ending its life as a feeble neutron star.

The key to understanding Betelgeuse's fate is to establish why it loses so much mass. As it fuses higher elements, its bloated atmosphere expands and its surface gravity weakens, shedding 1 million-times more mass, per year, than the Sun. Rather than a solar wind, Betelgeuse pumps out a hurricane of giant plumes. A multi-layered pulsating 'shell' of ejected material lingers around the star and might be responsible for a 15 per cent contraction in its apparent size.

Astronomically speaking, Betelgeuse's doomsday is close. And the effect on our descendents? Comfortingly, it is too far away to cause us any harm.

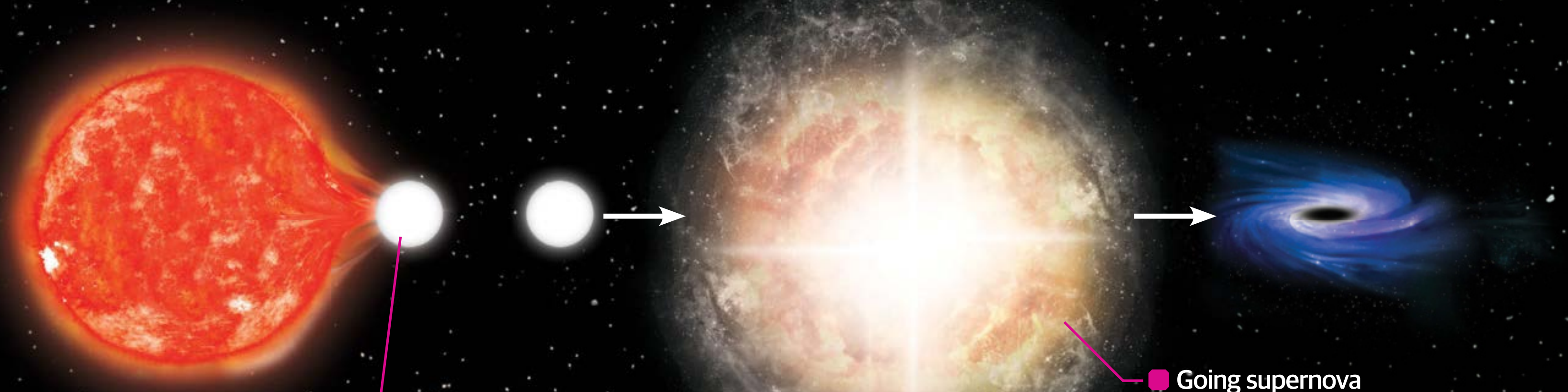
A giant's explosion from Earth



1 From Earth, Betelgeuse forms the right shoulder of Orion the Hunter. Although it's young, it has progressed rapidly through its stellar evolution and is close to supernova.

2 The sheer magnitude of the death of Betelgeuse – one of the largest known stars – will make itself apparent in Earth's skies. It should remain visible for several months.

3 When the light from its demise reaches us, after travelling 640 light years, Betelgeuse will greatly outshine the Moon in our night sky.



Stellar eating
IK Pegasi-B begins to siphon material away from Pegasi-A's gaseous envelope.

Going supernova
IK Pegasi-B falls victim to the Chandrasekhar Limit, which might induce gravitational collapse. It will then evolve into a neutron star or black hole, or a Type Ia supernova.

8 Mu Cephei

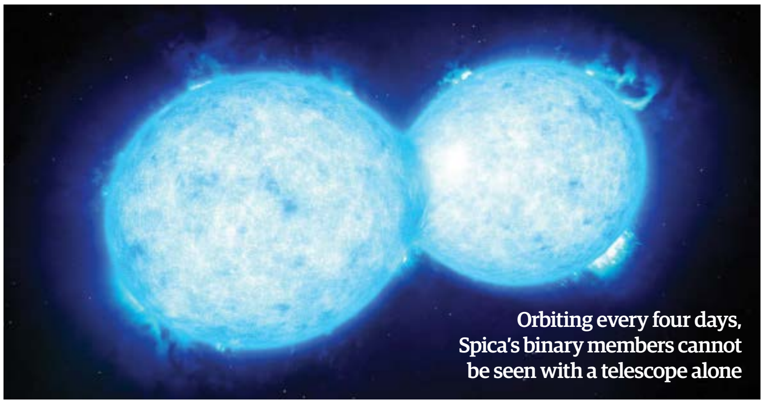
The garnet explosion

Probably less than a million years

Midway between VY Canoris Majoris and Betelgeuse, the red supergiant Mu Cephei is one of the largest stars known to humanity. With a luminosity around 100,000-times greater than our Sun, and with a radius pegged at around 1,260 solar radii, its rich reddish hue led the 18th century astronomer William Herschel to describe its "very fine deep garnet colour", which he likened to the red giant Mira. As a result, Mu Cephei very quickly earned the moniker of 'Herschel's Garnet Star'.

A 10-million-year-old variable star, records of its changeable magnitude - which varies between 3.4 and 5.1 - have been maintained continuously for more than 130 years, although its distance has been tentatively determined in the range of 6,000 light years. Mu Cephei may be surrounded by a vast 'shell', perhaps as much as 3,000 years old, which extends outward to a distance of about one third of the star's radius. This dusty shell is known to be somewhat asymmetrical in shape, perhaps torus-like, and Mu Cephei is thought to be losing several solar masses worth of material each year.

Despite its relative youth, Mu Cephei has already exhausted its hydrogen supply and is in the process of fusing helium into carbon. As is the case with many large stars, the conversion of elements to iron will precipitate the final cataclysmic collapse of the core, a spectacular supernova and a feeble remnant of what once was. It seems plausible that Mu Cephei will die in a Type II supernova - rapidly collapsing and violently exploding within a million years - although the form its remains will subsequently take is unknown.



Orbiting every four days, Spica's binary members cannot be seen with a telescope alone

9 Spica

Our nearest supernova

A few million years

Deep in the constellation of Virgo lies the binary system of Spica: a pair of stars so close together that neither is spherical, but gravitationally distorted and egg-shaped. Separated by just 17.7 million kilometres (11 million miles) - a tenth of the gap between Earth and the Sun - the brighter 'primary' and its smaller, dimmer companion orbit one another every four days. They cannot be seen separately through a telescope and can only be resolved by spectroscopy and analysing minute variations in magnitude.

The blue-white Spica has been observed for thousands of years, with Egyptian temples of the 3rd millennium BCE oriented to face it. Only in modern times has it been possible to discern its nature as a binary system and lunar occultations have revealed that Spica actually comprises of five objects. But for the purposes of supernova-spotting, Spica's primary takes centre-stage.

It consists of a rapidly-rotating blue giant variable star, about 10.5 times as massive as the Sun. Coupled with temperatures as high as 22,127 degrees Celsius (39,860 degrees Fahrenheit) - four-times hotter than the Sun's visible surface - and a luminosity 12,100-times greater than our own star, Spica's primary is in pole position to become a Type II supernova in a few million years from now.

10 VY Canoris Majoris

The big bang

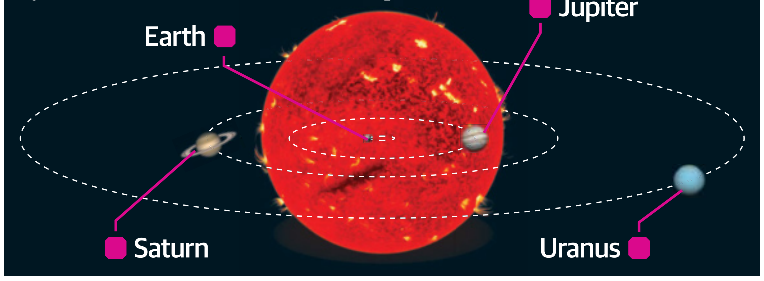
Possibly a few million years

VY Canoris Majoris is big. In fact, at 1,420 solar radii, it is one of the ten largest stars known to humanity. If it were set at the centre of our Solar System, it might extend past the orbit of Jupiter, almost as far as Saturn, and wholly consume all four innermost rocky planets, including Earth. Before its radius was determined by the ESO's Very Large Telescope, it was theorised that VY Canoris Majoris might even be as big as 2,100 solar radii. Fortunately for us, this red hypergiant resides in the constellation of Canis Major, about 4,500 light years away from us.

With recorded observations dating back more than two centuries, astronomers have long been aware of its crimson hue and changeable magnitude. At first, it was theorised that it was a multiple-star system, but more recent imaging has revealed bright concentrations within a vast surrounding nebula and VY Canoris Majoris has no stellar companions. Hubble data has revealed that this nebula is structurally similar to at least one yellow hypergiant, prompting suggestions that it might follow this evolutionary route before eventually becoming a Wolf-Rayet star.

Over the past thousand years, it has experienced many localised eruptions, forming loops, arcs and knots of material as it approaches the end of its life. Today, VY Canoris Majoris has probably shed around half of its mass as it continues to exhaust its nuclear fuel and draws inexorably closer to a likely supernova.

If VY Canoris Majoris was at the centre of our Solar System, it would swallow the four inner planets



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An interview with...

Neil deGrasse Tyson

The host of *StarTalk* has become one of the world's best-known astrophysicists, popularising space and science for millions

Interviewed by David Crookes

> "I'm intrigued by the idea that we are a record of something playing out in another way inside of a black hole's event horizon"

INTERVIEW BIO

Neil deGrasse Tyson
As the founder of the Department of Astrophysics at the American Museum of Natural History in 1997 and director of the Hayden Planetarium at the Rose Centre for Earth, Neil deGrasse Tyson has his fingers in many pies. For most of us though, he is the author and astrophysicist who regularly writes books and appears on our television screens. His numerous appearances on various US TV shows from *The Universe* to *The Colbert Report* have brought the delights of space to the masses. He has also hosted a weekly podcast called *StarTalk* since 2009, which was turned into a spin off TV show on National Geographic two years ago.

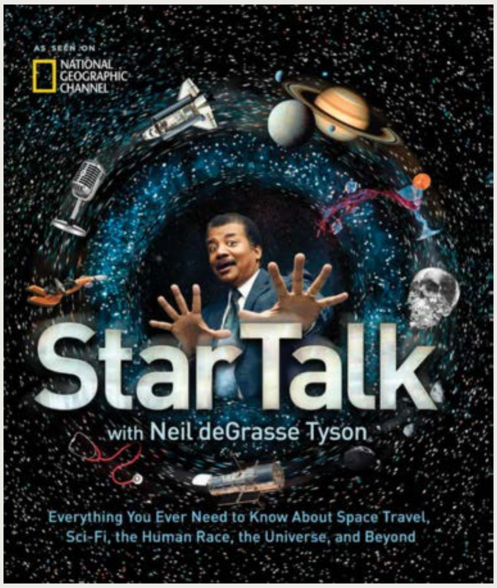
Over the years, you've gained a reputation for helping to make science and space accessible to the wider population. How do you go about hitting the right spot for people - what do you think grabs their attention?
I've thought a lot about what might interest a disinterested person and I have thought more about the impact of what I'm saying than you can possibly believe. I could say something off the cuff, and you'd say, "Oh man that's really cool, that's great, how have you just figured that out?" And I'd think, "No, I've thought about this and I've watched you react to things I've said - I know what you're going to find interesting." When I'm talking to people, I'm looking to see if they've raised their eyebrows or if they look bored or excited. I have a mental inventory of things that enchant and bore people and the things that people want to hear more of. I bring that to my lectures, books or *StarTalk*.

Let's discuss *StarTalk*. The podcast has been around since 2009, but where did the idea come from and what was your aim?
Three of us started the concept. Myself and my co-executive producers Helen Matsos, who is a NASA astrobiologist, and David Gamble got together and realised there was an unserved population out there who, in our judgement, would enjoy science but didn't know that they would. We figured there was a population that does not buy science books or write on the calendar when a science programme is coming on television - people who are kind of oblivious to it. And we thought we might be able to create a media product that would attract them.

But in addition to that, we realised there was a demographic of people who are sure that they do not like science. Maybe they didn't do well in their science class and they spent the rest of their life avoiding it. We thought we might be able to reach to them as well. So *StarTalk* became a synthesis of pop culture, science and comedy.

Why did you go for that mix?
Well, we realised that if you attach science to pop culture, you don't have to explain the pop culture parts. People know the famous actor, the famous singer or famous politician and if they become my guests, and if my conversation with them explores science, then fans will follow them to the show and we get to expose people to science and show them how ubiquitous science is in their lives. We get to show them that it's even touching their favourite person. So in the studio, I have my co-host, a professional comedian, and I typically bring in an academic on a particular subject that we cover in the interview with the pop culture person. The comedian is a valve of levity and the expert is a valve of gravity and I control those valves in such a way so that the listener can get, in my judgement, the right balance of science, as it appears in everyday life. And you end up smiling along the way. So this was an experiment and we proposed this to the National Science Foundation and they agreed it would be interesting.

***StarTalk* has made the transition to television and it's the first weekly late-night show to be based on science. It's also been nominated for an Emmy. But how comfortable have the guests been about science and have you been surprised at the science knowledge some of them have?**
It cuts two ways. I like to think of pop culture on *StarTalk* as the scaffold on which we place scientific topics so my interviews are never to test the person to see how much science people know. That's not the point. What I want to know is how much science *interest* they might have, and if they don't have any interest, that becomes the challenge; for me to find ways that science has touched their lives. So with [former US president] Bill Clinton, my favourite story was of him sitting around the table in the Oval Office with some important heads of state not agreeing on something. He said he had borrowed a Moon rock from NASA that he kept in the centre of the table and every time there would be some conversational


AS SEEN ON
NATIONAL GEOGRAPHIC CHANNEL
StarTalk
with Neil deGrasse Tyson
Everything You Ever Need to Know About Space Travel, Sci-Fi, the Human Race, the Universe, and Beyond

StarTalk fuses pop culture with science, space and comedy to create a show that excites and engages the masses

The weirder the universe is, the better for Tyson, but he claims what matters most are the things you can measure, detect and interact with, not just theories

The idea that we are a record of something playing out in another way inside of an event horizon - known as the hologram hypothesis - intrigues Tyson

> "There are strong theoretical arguments for a multiverse but it's not clear how you would get evidence for it"

political impasse, he would point to the rock and say, "That rock is from the Moon." It gave everyone some cosmic perspective and by playing the science card on everybody, they were playfully taken aback and could have a fresh conversation on what they needed to agree on. It's interesting to know that a head of state would do that.

You're not afraid of tackling some big ideas of space. We noticed recently that you said the universe could be a simulation. Why do you think that's the case?
So I was slightly misquoted there and, you know, headlines take liberties and they become click bait for others if you're surfing the internet. What I said was that I think it would be really cool if we were some alien simulation, maybe someone's PhD thesis experiment. It would be like, "I wonder what would happen if we set up these laws of physics and these laws of chemistry and biology and let's watch." And then I wonder if the aliens would start getting bored and start to throw in things to disrupt what might be a peaceful, tranquil world. But there are serious, philosophical questions and conversations about physics being conducted around this.

If we were in a simulation, do you think we would be able to tell?
One of my favourite references to this was from a colleague of mine, Max Tegmark who is a professor of astrophysics at the Massachusetts Institute of Technology. He said to imagine you're playing a game of *Mario* - any of the *Mario* video games - and let's say you are in the game. You start taking measurements and you say, "Okay, if I jump, I jump this high and the other characters don't jump as high as I do." So you start setting up laws of motion that apply inside the game and eventually you might figure out all the laws of motion and that is your world. But is that anything different to what we're doing with our branches of science? We're trying to figure out the laws of nature.

Well, where do those laws come from? It's still a little bit of a mystery. Religious people would say God made the laws but if you're more prone to secular accounts of things, you might ask are these coming about naturally or by hand, by someone who has created our world for their own entertainment? And then you get deeply philosophical and say if we are a simulation of some super intelligent alien species, is that indistinguishable from the concept of God? That's another interesting topic to have a debate over a beer at a bar on, something to start arguing about because everyone is going to have an opinion no matter how much or little research they have done on the subject.

Many similar debatable subjects have surfaced of late. Do you believe our universe is just one of an infinite number?

It's not a matter of what I believe in. I don't know that there is anything I believe in. That implies that I don't have any evidence for what I think is true. No, there are compelling arguments out there for why there might be a multiverse and they are grounded in physics and sometimes quantum physics, and I sometimes find them compelling enough to invest more thought into what it might be like. The idea of multiple universes is a high concept idea and people have a bit of armchair philosopher in them. It's fun to be able to tap that urge for people to want to think that way.

There is no hard and fast evidence of a multiverse, is there?
No, there's no evidence. There are strong theoretical arguments for why we might have a multiverse but it's not clear how you would get evidence. If you have no access to it, then what does it mean for you to hypothesise the existence of something that you will never detect? One of the things we've learned in science is what matters are the things that you can measure, detect and interact with. If you can't interact with it, does it even make sense to talk about it? But if you're intellectually active, you will talk about it.

The idea of the universe being a simulation is different to hologram theory, but do you think the hologram principle could hold some truth?
The hologram hypothesis is intriguing. You come up with it when you have an event horizon around a black hole and I'm intrigued by that, this idea we are a record of something playing out in another way inside of an event horizon.

So what intrigues me from the point of physics is that certain other things we know are true want us to think this way about the event horizon and that there would be a hologram. Those are the interesting hypotheses in physics, where other things that are tested and you know to be true are logically required for other things to be true. So I'm still following that space to see the next wave of development in it. But I'm all for it. The weirder the universe is, the better.

One thing we picked up a couple of years ago was your fear that we've been visited by intelligent aliens who have seen life on Earth and believed it to be unintelligent. Do you think there is life out there that has tried to contact us?
I just wonder, not only whether we have we been visited by extremely intelligent aliens, but whether we were simply not interesting enough to them because we're too stupid as a species. It's like, are worms interesting to you, unless they are your research speciality? Do you walk down the street, see a worm, pause and reflect? "I wonder what that worm is thinking? Let me see." No, you step on it or you walk by. It does not intrigue you. So if plenty of life forms on Earth are not interesting enough to stop you in your tracks, then why couldn't there be life forms vastly more intelligent than humans that see Earth as this boring place of DNA-based life and move on? We would do that, and we already do that with other forms of life on our own planet.

The other possibility is they are so intelligent that they created a simulation - and this is, of course, the simulation hypothesis, again, that they created us for their own entertainment. So these are some things to talk about, perhaps. Whether or not they are grounded enough in scientific peer-reviewed papers, they are fun to talk about in a bar over a drink.

On a lighter note, we've heard you're starring as Neil deBuck Weasel in the upcoming movie *Ice Age: Collision Course*. How was that?
[Laughs]. Oh, that's very short. I'm only in it for a couple of minutes. I think it's novel that I'm in the movie but it's very brief; I'm helping another character try to save the world by using physics. I don't want to over-think my role in this.

And you also have a new book on its way. What subjects are you delving into?
The book is the soul of *StarTalk*. It is the show turned into something that you can carry with you and open and dip in to, and it is a celebration of all the ways science has, does and will continue to touch our lives. Since it pivots on this pop culture scaffold, it means every page you turn to, you have an entry point because all the entry points are pop culture pathways that go in. So we are proud of this as a creative work, to take content stimulated by the show and take it further in printed form.

Neil deGrasse Tyson on set of the filming of *StarTalk* for National Geographic on 24 June 2015. His show has been running since 2014

Tyson wonders whether we have already been visited by extraterrestrials but were deemed not interesting enough to contact

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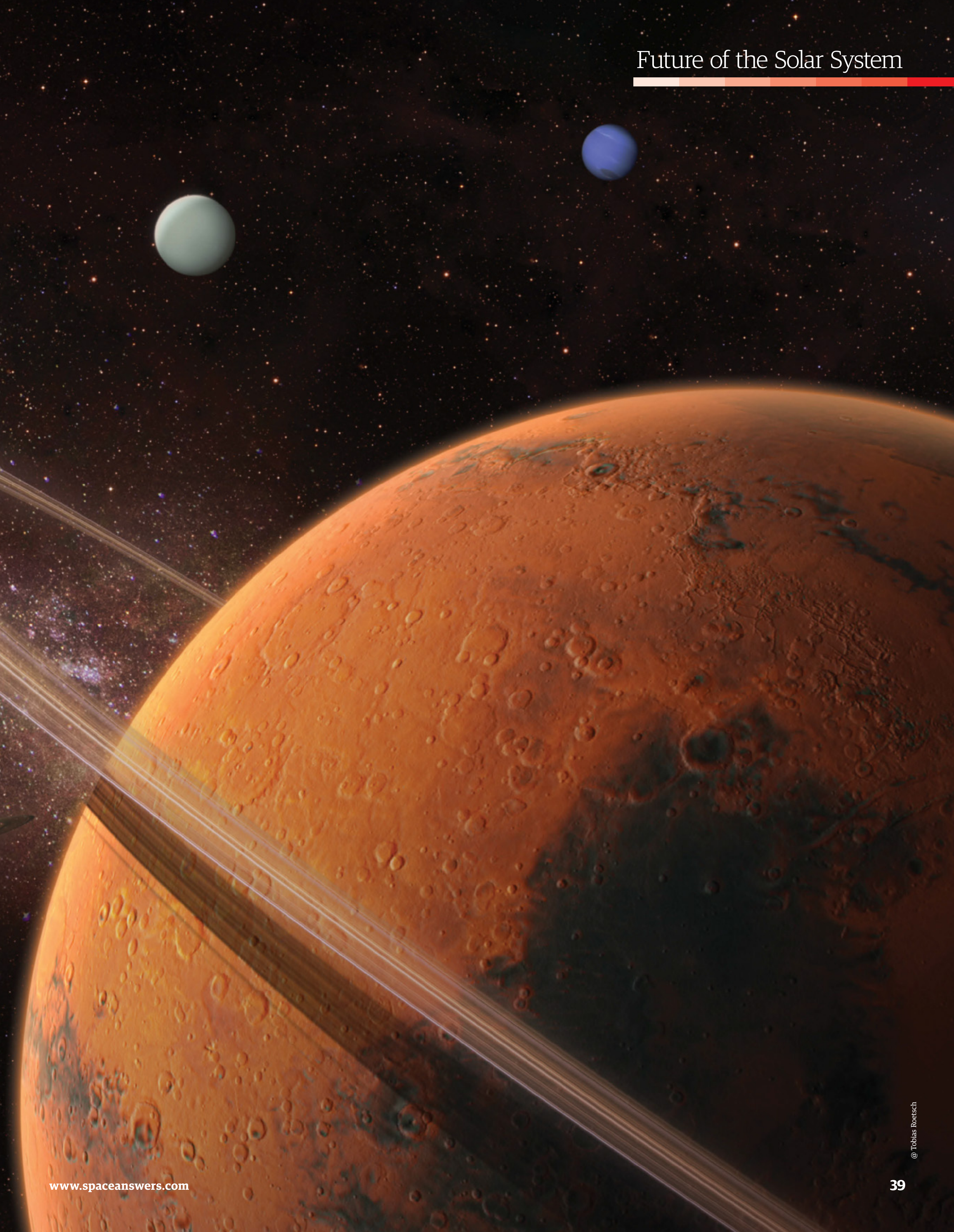
Future of the Solar System

It may be a model of long-term stability, but our solar neighbourhood's future holds some cataclysmic events and spectacular changes

Written by Giles Sparrow



@ Tobias Roetsch

Ever since it settled down from a period of early turbulence about 4 billion years ago, our Solar System has provided a more or less stable home to Earth and the planets that orbit the Sun. But how long will it stay that way? It's certain that the Sun is ultimately doomed to brighten and swell enormously in size, becoming a red giant whose bloated outer atmosphere will threaten to engulf the Solar System's inner worlds in 7 billion years time - but long before then there are sure to be other changes that alter our planet and others, perhaps beyond recognition.

In the relatively near future, it is tidal forces between planets and their satellites that are likely to have the most impressive effects. These arise as angular momentum is transferred between the planet and moon due to tides on the planet and in response to the moon's gravity, resulting in a consistent 'tug' on the moon's orbit. For most moons in the Solar System, the result is that the satellite slowly spirals away from the planet, while the planet slows its rotation. This is what is happening in our own planetary system - the Moon gets an average of 3.8 centimetres (1.5 inches) further away from Earth each year, while Earth's rotation slows by 1.7 milliseconds per century. Over millions of years, then, the orbits of most moons in the Solar System will get wider.

But for a couple of moons, the opposite is happening - they're slowly spiralling towards their planets. One of these is Phobos, the inner of Mars' two rocky moons - but why is it different? "The inward migration of Phobos is due to the fact that its orbital period is slightly shorter than the rotational period of Mars," explains Professor Ben Black of the City University of New York. "So the Martian tidal bulge tugs at Phobos like a dog-walker pulling on a leash." Alongside graduate student Tushar Mittal, Black recently looked at the Martian moon's future evolution, and suggested that in about 20 to 40 million years from now, Phobos may reach a crisis point, when it gets too close to Mars.

Previous calculations had revealed how long it would take for the 20-kilometre (15-mile) moon to migrate inwards, but Black and Mittal's work suggests Phobos might not make it that far. "We predict that Phobos won't make it all the way to Mars, but instead will break apart sooner than that," says Black. "We find that the key to Phobos' fate is its strength. If Phobos is sufficiently strong, tidal stresses won't be able to tear it apart, and it will crash into Mars intact. But the evidence points to Phobos being very weak."

"We considered the possible fates of Phobos in a self-consistent manner and utilised models developed in terrestrial rock physics - geo-technical models like those used in the construction of tunnels," adds Mittal. The result? Phobos' structural weakness means that it will disintegrate to form a rocky ring system around the Red Planet, similar to the icy ones seen today around planets like Saturn. "The lifetime of the ring will depend on how far Phobos is from Mars when a break-up occurs," points out Black, "but we estimate that the ring will persist for in the ballpark of 1 to 100 million years."

Beyond tidal forces, gravity has another important role to play in the future of the Solar System - one whose effects can be remarkably hard to predict. 'Orbital resonances' occur when one object has an orbital period close to an exact multiple of another. This produces frequent close alignments between the two, magnifying otherwise weak gravitational forces and potentially disrupting apparently stable orbits. A present-day example are the 'Kirkwood gaps' - regions of the asteroid belt between Mars and Jupiter that are empty because any object orbiting within them would be in resonance with Jupiter. But in the longer term, a different resonance with Jupiter might cause far more dramatic results.

Mercury, the innermost planet, has the most eccentric orbit of all, and the long-axis of this orbit wobbles or 'precesses' around the Sun at a rate of 1.5 degrees every thousand years. Jupiter's orbit, though less eccentric, precesses at a very similar rate, which could potentially allow their orbits to line up in a resonant arrangement around 3 to 4 billion years from now. If this was to happen, Mercury's orbit could eventually go haywire, flinging it onto a chaotic course that could send it hurtling into the Sun, or cause it to collide with either Venus or Earth.

In 2009, French astronomers Jacques Laskar and Mickaël Gastineau attempted to estimate the chances of such an event happening. Over 2,500 computer simulations, each of which varied the initial position of Mercury by a metre, found that Mercury's orbit evolved to threaten the other planets one per cent of the time. The tests reveal an example of 'sensitivity to initial conditions' - better known as chaos theory - which has profound implications for any attempt to track the long-term orbits of the planets.

Chaos theory doesn't mean that a system ignores the laws of physics - only that those laws operate in

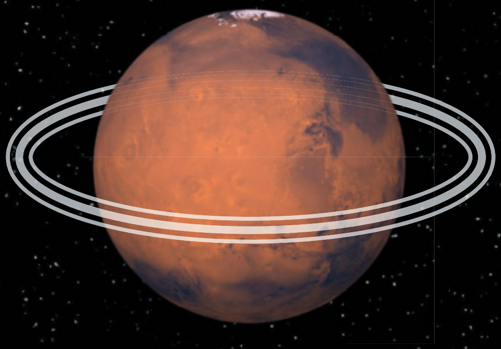
> "As the Sun brightens, the habitable zone will also expand, leaving Earth behind in about 1bn years" **Robert Smith, University of Sussex**

How Mars will gain a ring

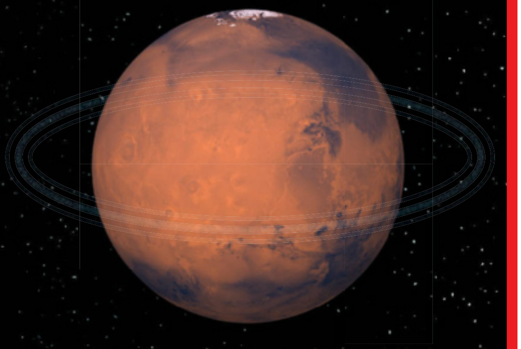
The disintegration of inner moon Phobos will create a ring around the Red Planet about 20 million years from now

1 Spiralling inwards
Because Phobos orbits so quickly, the tidal bulge it creates on the planet acts to tug it backwards, removing energy and sending it spiralling inwards.
Present day

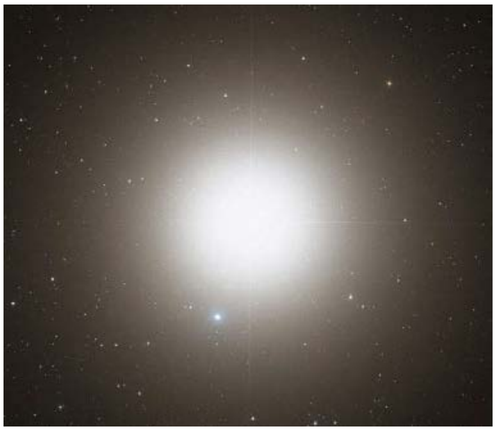
2 Tidal breakup
Eventually, Phobos drifts within Mars' Roche limit – a zone within about 3,620km (2,250mi) of the surface, where gravity makes it impossible for a large body to orbit.
Around 20 million years from now



3 Ring formation
As Phobos breaks apart, its fragments scatter along its orbit and, through the jostling effect of collisions, fall into a flattened ring.
Around 20 million years from now

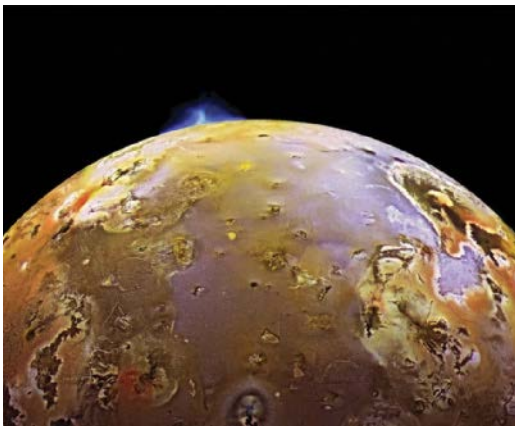


4 Ring decay
Tidal forces continue to act on the ring, causing debris to sift down onto the surface and eventually draining the ring of material.
Around 20-120 million years from now



Arcturus, in the constellation of Boötes, is a solar-mass star some 37 light years from Earth, which has recently begun its expansion into the red giant stage of its life

Volcanoes on Jupiter's moon Io are driven by heating from tidal forces, but as Io spirals away from the planet, these forces will weaken and the moon will cool



Graduate researcher Ben J Fulton and his colleagues at the University of Hawaii are investigating whether new planets could form in the aftermath of the Sun's burn out

> "White dwarfs are like hot embers after a fire goes out. They start bright and hot and slowly cool for the rest of eternity"

such a way that tiny differences in initial parameters magnify over time, until they make prediction impossible. In our Solar System, this means that unless you can pin down the exact positions, orbital speeds and masses of the eight major planets and countless smaller objects with near-absolute precision, attempts to model the evolution of orbits become useless after a certain point in the future. Estimates of exactly how soon we "lose track" of various Solar System parameters range between 2 and 200 million years – beyond that point, the positions of the planets and even the shape of their orbits are unpredictable using present-day models.

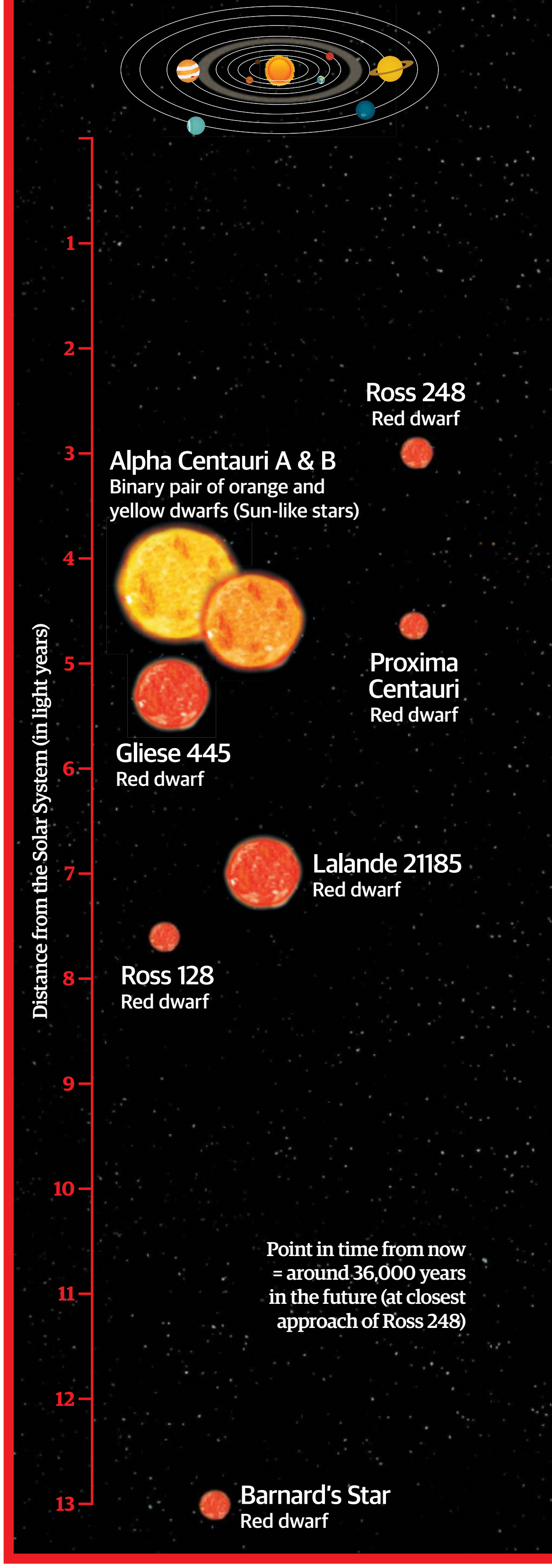
Another complicating factor is the gravitational influence of other stars. Today, the closest known star to Earth is Proxima Centauri, a small red dwarf some 4.25 light years from Earth, but astronomers have calculated the motion of other stars in the solar neighbourhood and found that several will come much closer than that in the next thousands of years – perhaps even close enough to have their own effect on the orbits of the outer planets and the icy objects of the Kuiper Belt and Oort Cloud.

While we are uncertain about the destiny of the planets beyond a certain point in the future, we're on firmer ground when it comes to the fate of the Sun itself. As it continues to shine by nuclear fusion of the hydrogen in its core, the Sun will brighten slowly but steadily over the next 4 billion years, at a rate of about one per cent every 100 million years or so. This will have severe consequences for the habitability of our own planet and others, but these consequences are nothing compared to what comes next.

In about 7 billion years from now, the Sun will exhaust the hydrogen fuel in its core, and begin to go through a series of dramatic changes. The exhausted, helium-rich core will begin to contract, releasing gravitational energy, while hydrogen fusion

Stellar switch

The next 100,000 years will see many stars make close approaches to our Solar System, though none should come close enough to threaten the inner planets



Point in time from now = around 36,000 years in the future (at closest approach of Ross 248) moves out into a surrounding shell. About half of the energy released by the contracting core is available to raise its temperature - eventually this makes it hot enough for the helium to undergo nuclear reactions, producing carbon and oxygen, but in the short-term it also heats the hydrogen-burning shell, causing fusion to run faster than it did in the core and increasing the Sun's energy output at least a thousandfold. The other half of the energy drives the expansion of the Sun's upper layers, using them to balloon outwards, creating a bloated, brilliant monster with a surprisingly cool surface - a red giant.

But just how large will the red giant Sun become, and will it threaten to engulf the planets that it has previously provided with light and heat? Robert Smith of the University of Sussex researched these questions with his colleague Klaus-Peter Schröder, of the University of Guanajuato, Mexico, and reveals a surprising factor that complicates the question:

"As the Sun becomes larger, the surface gravity also decreases, and mass is less strongly bound to the surface. Mass loss caused by the solar wind [the stream of particles blowing out from the Sun's surface] therefore increases steadily and becomes significant. By the time that helium ignition takes place in the core, the Sun will be more than 200-times larger than it was on the main sequence, reaching out beyond the Earth's current orbit. But it will also have lost about 20 per cent of its mass."

Due to the Sun's weakening gravity, the orbits of the planets will spiral outwards. The effect won't be enough to save Mercury or Venus (if they are still near their current orbits), but it might be enough to save Earth - if not for another twist in the tale.

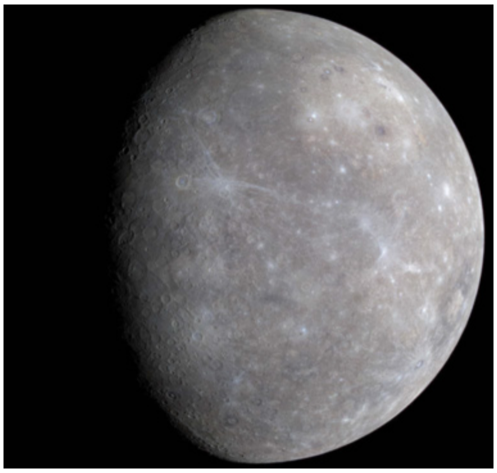
"As the Sun expands and loses mass, its rotation rate slows down," says Smith. "By the time it is 200-times larger than its current radius, its rotation period will be 2,500 years instead of one month. For Earth, this has a drastic consequence: as it orbits past a Sun whose surface is now rather close, it raises a tidal bulge on the Sun's surface. As it moves ahead of the bulge, this exerts a tidal drag on Earth, causing it to lose energy and spiral in towards the Sun. Interaction with the Sun's outermost atmosphere introduces a further drag force - the combined effects of these two forces is enough to cause a fatal spiral into the Sun, and the vaporisation of Earth."

Earth, it seems, is doomed by a very similar effect to that which is currently pulling Phobos to its fate. But what would be the effect of these dramatic changes further out in the Solar System?

"The increased luminosity of the Sun means that all the planets also heat up, with some of them becoming potentially habitable (having a mean temperature similar to that of the present Earth)," explains Smith. "There is a habitable zone in the Solar System in the form of a ring, which currently only includes the Earth near its inner edge. As the Sun brightens, the habitable zone will expand, leaving Earth behind in about 1 billion years. Unfortunately, the habitable zone moves rather slowly for most of the Sun's red giant evolution, speeding up only in the last half-billion years before helium ignition. This means that Mars, for example, will only enter the

> "Earth, it seems, is doomed by a very similar effect to that which is currently pulling Mars' moon Phobos to its fate"

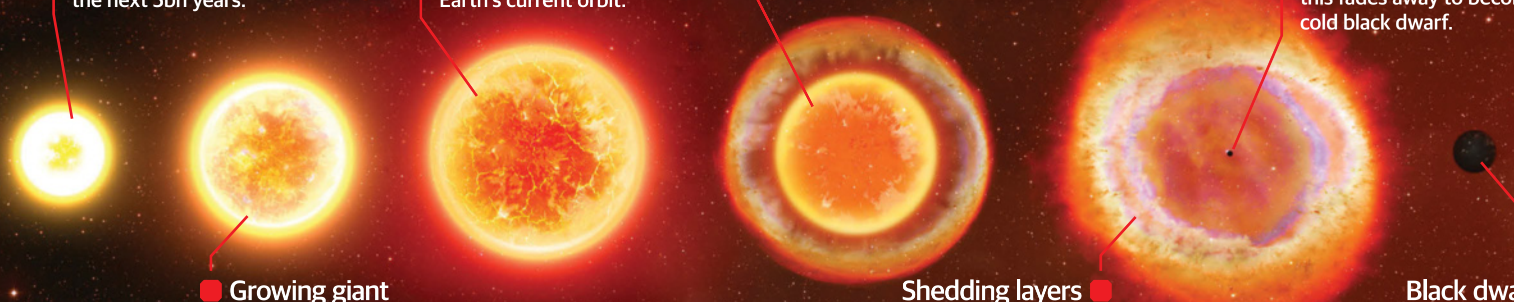
About 500mn years from now, the Moon's slow drift away from Earth will mean it can no longer cover the Sun's disc in a total solar eclipse



Computer models suggest that distant Jupiter could one day tug Mercury out of its current orbit and send it careening across the inner Solar System

The Sun's evolution to a black dwarf

The long-term fate of the Solar System is governed by the star found at its centre. Fortunately, we have several billion years before the Sun goes through any major changes



Ageing Sun
As our star uses up the hydrogen fuel in its core, it brightens slowly over the next 5bn years.

Growing giant
As hydrogen fusion moves into shells around the core, the Sun brightens and swells in size, with its surface growing cooler.

Monster star
At its greatest extent, the Sun will probably have a diameter equivalent to Earth's current orbit.

Unstable phase
After a brief respite as the core reignites and fuses helium, the Sun swells again, entering a period of pulsations in brightness and size.

Shedding layers
The Sun becomes ever more unstable and its outer layers are blown off to form a spectacular, but short-lived, planetary nebula.

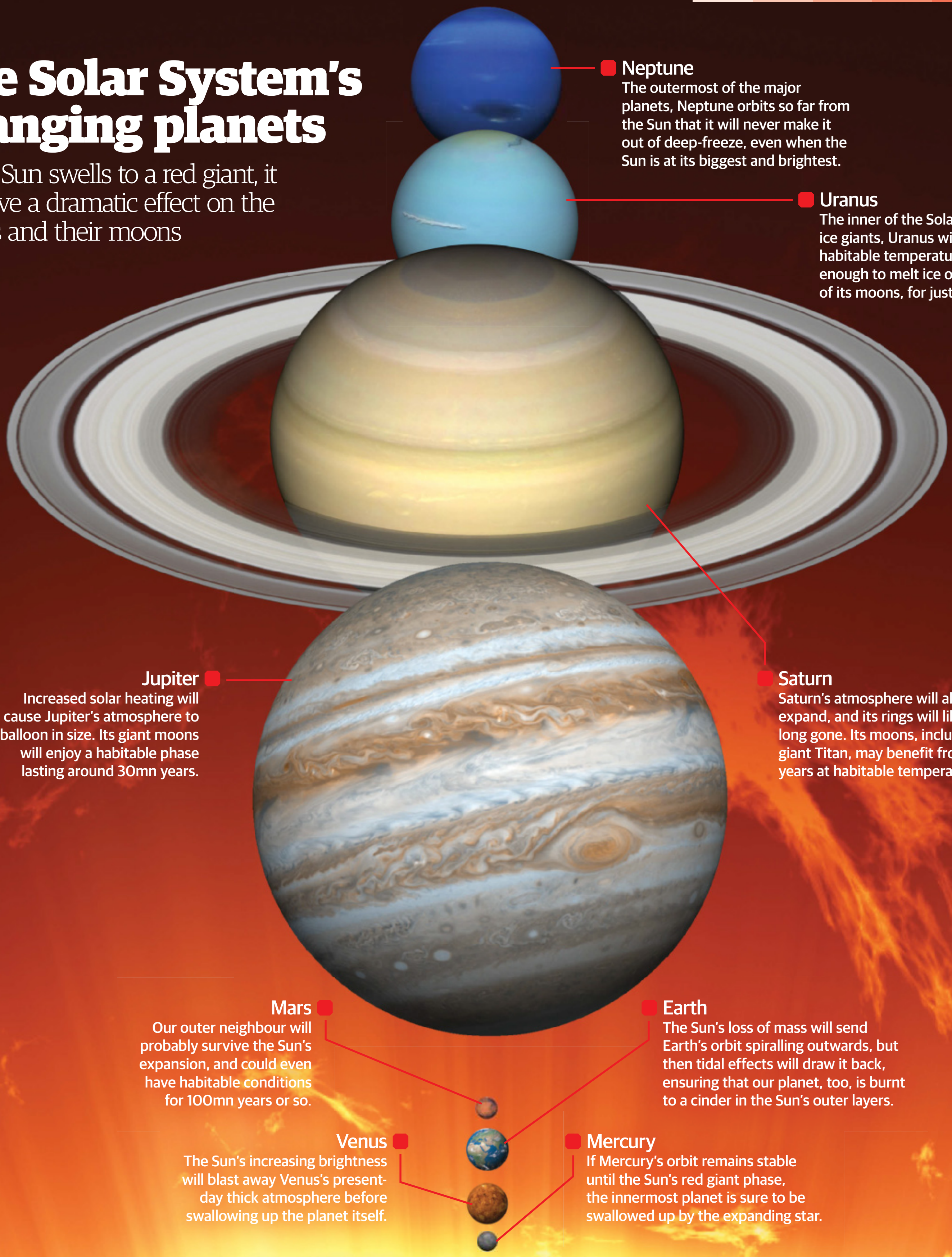
White dwarf remnant
Eventually the Sun's core is exposed as an incandescent, slowly cooling white dwarf star. Over billions of years, this fades away to become a cold black dwarf.

Black dwarf
Due to the time it takes for them to evolve, a black dwarf has never been observed.

@ Tobias Roetsch

The Solar System's changing planets

As the Sun swells to a red giant, it will have a dramatic effect on the planets and their moons



Neptune
The outermost of the major planets, Neptune orbits so far from the Sun that it will never make it out of deep-freeze, even when the Sun is at its biggest and brightest.

Uranus
The inner of the Solar System's two ice giants, Uranus will experience habitable temperatures, warm enough to melt ice on the surface of its moons, for just 2mn years.

Jupiter
Increased solar heating will cause Jupiter's atmosphere to balloon in size. Its giant moons will enjoy a habitable phase lasting around 30mn years.

Saturn
Saturn's atmosphere will also expand, and its rings will likely be long gone. Its moons, including the giant Titan, may benefit from 8mn years at habitable temperatures.

Mars
Our outer neighbour will probably survive the Sun's expansion, and could even have habitable conditions for 100mn years or so.

Earth
The Sun's loss of mass will send Earth's orbit spiralling outwards, but then tidal effects will draw it back, ensuring that our planet, too, is burnt to a cinder in the Sun's outer layers.

Venus
The Sun's increasing brightness will blast away Venus's present-day thick atmosphere before swallowing up the planet itself.

Mercury
If Mercury's orbit remains stable until the Sun's red giant phase, the innermost planet is sure to be swallowed up by the expanding star.

Colonising the Solar System

Earth has a few billion years left before the brightening Sun makes its surface uninhabitable – so where could we go next?

🕒 Year likely to happen
▲ Type of habitat
🌡 Temperature at time of colonisation
◗ Atmospheric constituents at time of colonisation

The Moon

🕒 2050

🌡 -180°C to 120°C (-292°F to 248°F)

▲ Pressurised environment

◗ No atmosphere – however, this means that environmental conditions on the Moon will change less dramatically than they will back here on Earth.

Mars

🕒 2100

🌡 -55°C (-67°F)

▲ Pressurised environment or terraformed planet

◗ Carbon dioxide – but planetary engineering could trigger a greenhouse effect and release trapped ice, warming the planet to produce a breathable atmosphere.

Callisto

🕒 2200

🌡 -140°C (-220°F)

▲ Pressurised environment

◗ None. Callisto would remain too cold to terraform until the Sun enters its red giant phase, but is the safest of all Jupiter's moons in terms of radiation risk.

Titan

🕒 2300

🌡 -180°C (-292°F)

▲ Pressurised environment

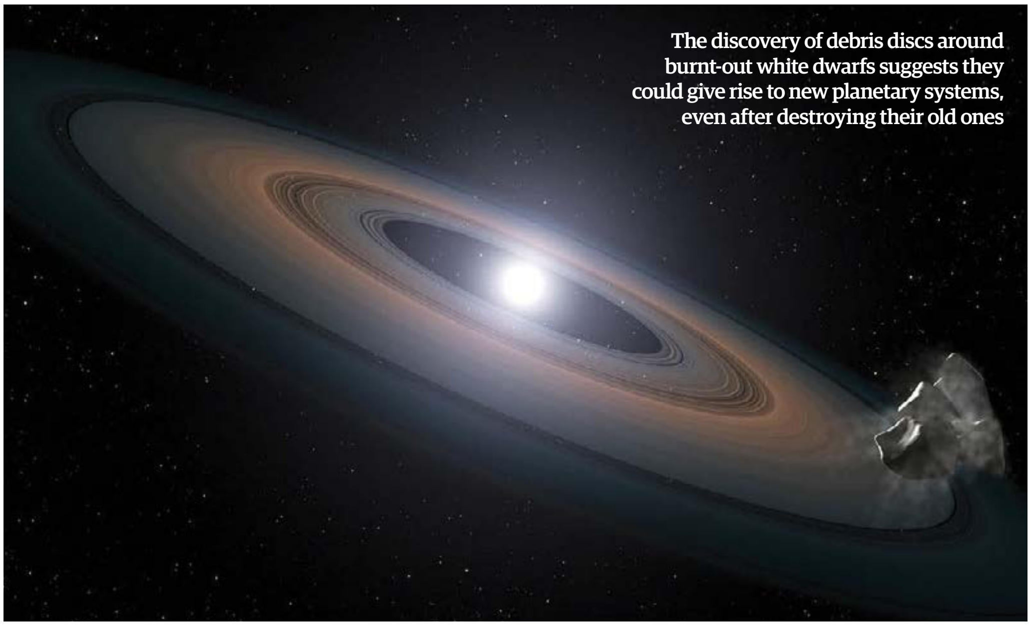
◗ Nitrogen and methane – although it will remain deep-frozen for billions of years, Titan has a thick atmosphere and many resources to support a human colony.

habitable zone 6 billion years after the Earth leaves it, and will stay in it for 100 million years."

Such periods are far too short for any life to evolve and take advantage of them, and before the habitable zone can reach the outer edge of the Solar System, the Sun will undergo another dramatic change. An event called the helium flash will see the core reignite, fusing helium into heavier elements. As its internal structure changes, our star will become much less luminous and shrink back rapidly, taking the habitable zone with it. Helium burning may last for about 100 million years before the core's supply of that fuel, too, is exhausted. After swelling to a red giant once again, the Sun will become unstable, discarding its outer layers in a small planetary nebula and ultimately leaving behind just the burnt-out, incandescently hot, planet-sized core – a white dwarf.

Is that the end for our Solar System? Remarkably, recent work by astronomers at the University of Hawaii suggests it might not be. Graduate researcher Ben J Fulton and colleagues investigated the possibility that new planets might form in the aftermath of the Sun's burnout, and asked whether they might be able to support life. "The idea is that the remains of these destroyed first-generation planets might be able to re-coalesce into a second generation of planets once the star runs out of hydrogen and helium, and contracts into a white dwarf," explains Fulton. The small size of the Sun's white dwarf remnant would make it far fainter than the present-day Sun, and mean that any habitable planets would need to orbit much closer in.

"White dwarfs are like hot embers left after a fire goes out," continues Fulton. "They start out bright and hot and slowly cool for the rest of eternity. This means that the orbital radius of the habitable zone around a white dwarf evolves with time. Just after the formation of the white dwarf, the habitable zone is relatively far away and evolving very rapidly, but as the white dwarf ages, the distance to the habitable zone moves inward and the evolution slows down. A planet orbiting at a distance of 0.01 AU will be within the habitable zone for 8 billion years, from about 2 billion years after the formation of the white dwarf."



The discovery of debris discs around burnt-out white dwarfs suggests they could give rise to new planetary systems, even after destroying their old ones

Compared to 'normal' exoplanet systems, such white dwarf planets might be rarer. Fulton and his colleagues carried out a survey and found that 'super-Earths' (planets twice the size of Earth) are expected in the habitable zones of seven per cent of white dwarfs. That is in contrast to estimates of 15 to 20 per cent for super-Earth-sized planets around Sun-like stars, but there are billions of white dwarfs out there. "Our survey was not sensitive to smaller planets or asteroidal debris, which have recently been discovered around a white dwarf," admits Fulton. "So it's possible that these smaller planets commonly orbit white dwarfs throughout the galaxy."

So even if the Solar System as we know it is doomed to die when the Sun expands into a red giant in 7 billion years time, it's comforting to imagine a new system of strange planets orbiting our burnt-out star in the distant future.

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The Automaton of Venus

A new NASA project is looking to send a walking, clockwork robot with mechanical programming to the second planet from the Sun

Despite being our closest neighbour, Venus has such a harsh environment that it is still relatively unexplored compared to Mars. Because its atmosphere is mostly carbon dioxide, the surface pressure is 92 times that of Earth's, and it has an average temperature of 462 degrees Celsius (864 degrees Fahrenheit), which is hot enough to melt lead. The Soviet Union managed to put eight stationary landers on Venus between 1970 and 1985, but the longest survivor only lasted 127 minutes. No missions have landed since.

The heat is the biggest challenge; systems and electronics could be embedded into solids or left open to accommodate the pressure (like deep sea submersibles), but with no way to dump heat, they will slowly cook. In an effort to get more long-term data from Venus, NASA JPL engineers Jonathan Sauder and Evan Hilgemann are working on an alternative approach, based on an ancient technology. Before electronics there was a long history of mechanical automata; the Greeks built the Antikythera automata, a mechanical astronomical computer around 2,300 years ago. By the 19th century mechanical programming was in use in settings from life-like, animated sculptures to industrial textile machinery. Now, such mechanisms may be the answer to surviving on Venus.

Sauder's project is the Autonomous Rover for Extreme Environments, or AREE. "Rather than try and get a lot of data for only minutes, we're looking to use purely mechanical systems to collect simple environmental data over weeks or months," says Sauder. Rather than batteries, AREE will use a wind turbine to keep a spring wound up, which will provide power for a 'Strandbeest' walking mechanism - an ingeniously simple system developed by Dutch artist, Theo Jansen, that produces a smooth walking motion with six crank driven legs. AREE will be controlled by mechanical sequencers - potentially pin barrels or punched strips - as it progresses across the landscape, and will be guided by reactive mechanisms that respond to difficult terrain intrinsically without the need for computer control.

AREE's instruments would also have to be mechanical; wind speed and direction could be collected from the turbine, temperature by bi-metallic strips that bend to a particular angle for a given temperature, and between steps it would place a seismometer down to listen for Venus-quakes. But how do you record data without computer memory, or transmit it off the planet? AREE might record LPs! It would capture sensor data by cutting it into grooves on a disc or cylinder like a phonograph, which then could be sent by balloon up to the benign upper atmosphere.

At 50 kilometres (31 miles) altitude, Venus' atmosphere is around 20 degrees Celsius (68 degrees Fahrenheit) and has a pressure similar to Earth's. This means that a variety of flying probes are envisaged to reside there in the future, and one of them could collect the records and transmit the data to Earth. Another possibility could be radar semaphore, with AREE adjusting the shape of a reflector so that a satellite could detect the changes by sending a radar pulse from orbit. JPL is also looking at the potential of mechanical logic circuits for storing data and maybe controlling AREE.

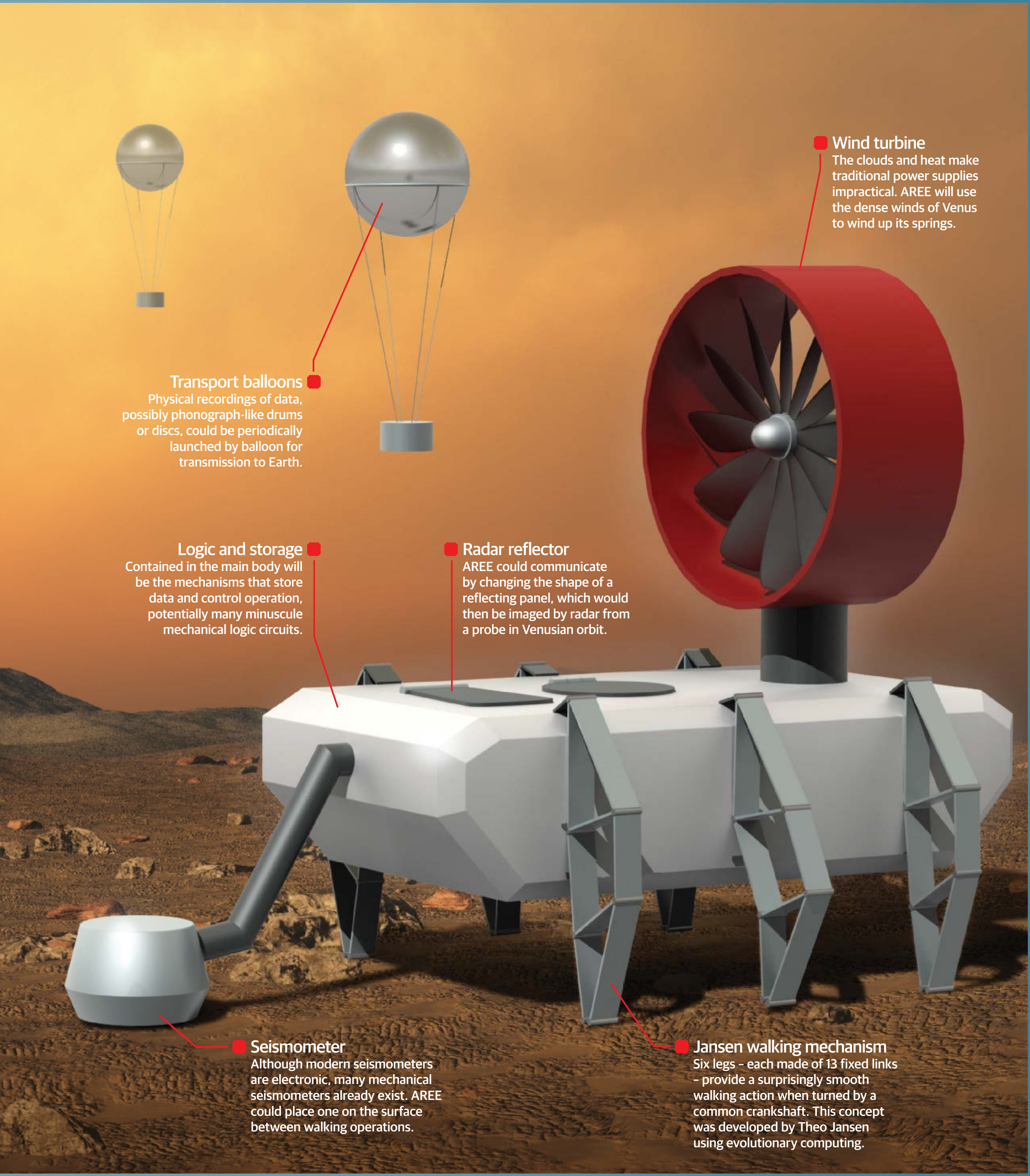
Computers are made up of huge numbers of tiny switches and circuits that use binary numbers to perform logical operations - things such as, "If this input *and* that input are both on, turn on that output." Complex computing is built out of such simple steps, but done incredibly quickly by tiny components. Sandia National Laboratories has demonstrated that mechanisms 50 micrometres across, with 8MB of mechanical storage, would fit on a flat, 40-centimetre (15.7-inch) square.

It is still in the early stages, but AREE is an ingenious solution to challenging environments - as well as Venus, it could be used on the searing surface of Mercury, or in the lethal radiation environment of Io. As seen in *Dr Who*, clockwork robots really might have a place in our future!

> "AREE will be controlled by mechanical sequencers - potentially pin barrels or punched strips - as it progresses across the Venusian landscape"

Flying probe
A flying probe exploring the benign upper atmosphere could collect the physical recordings from AREE, process them and transmit the data to Earth.

Venusian environment
The conditions on Venus' surface are hellish - 92 times the atmospheric pressure of Earth and hot enough to melt lead.



Wind turbine
The clouds and heat make traditional power supplies impractical. AREE will use the dense winds of Venus to wind up its springs.

Transport balloons
Physical recordings of data, possibly phonograph-like drums or discs, could be periodically launched by balloon for transmission to Earth.

Logic and storage
Contained in the main body will be the mechanisms that store data and control operation, potentially many minuscule mechanical logic circuits.

Radar reflector
AREE could communicate by changing the shape of a reflecting panel, which would then be imaged by radar from a probe in Venusian orbit.

Seismometer
Although modern seismometers are electronic, many mechanical seismometers already exist. AREE could place one on the surface between walking operations.

Jansen walking mechanism
Six legs – each made of 13 fixed links – provide a surprisingly smooth walking action when turned by a common crankshaft. This concept was developed by Theo Jansen using evolutionary computing.

© Adrian Mann

INTERSTELLAR TRAVEL

+ how to become a space tourist

Having explored much of the Solar System, attention is now turning to the stars beyond

Written by Colin Stuart

As the spacecraft approaches the planet, things seem quite familiar. Sunlight glints off an expanse of blue ocean, and white clouds are corralled by gusts of wind. But a closer inspection is jarring - the continents are all in the wrong place. That's because, for all its similarities, this isn't the Earth. Instead, we're looking at the first historic images sent back of another world orbiting a star far beyond the Sun. In days gone by, such ideas were little more than a pipe dream. But the tide, it seems, is turning.

Back in April, Stephen Hawking and Russian billionaire Yuri Milner launched their Breakthrough Starshot project to an enthralled press conference. Their goal is to one day fire lasers at sails strapped to tiny stamp-sized spacecraft, launching a swarm of explorers to Alpha Centauri - the nearest star system to the Earth. If successful, the journey might only take a few decades. Such interstellar travel is no longer an absurd idea according to Andrew Coates, a space scientist from University College London. "It is not completely pie in the sky," he says.

As things stand, we only have one distant emissary of humankind, one that has departed the planetary system in which we reside. That is Voyager 1 - the probe sent to explore the outer planets in 1977. In 2012, measurements of the solar wind suggested it had left the magnetic influence of the Sun - one way of arguing it has departed the

Solar System. Yet it is nowhere near the next solar system. That's the problem with space – it really lives up to its name. A trip to the Alpha Centauri system requires us to travel a staggering 40 trillion kilometres (25 trillion miles, or 4.37 light years). At the speed of Voyager 1 it would take at least 30,000 years to cover that distance.

That's why Hawking and Milner have turned to an alternative solution. Their goal is to take advantage of advances in technology miniaturisation. "We're already seeing one-tonne spacecraft being scaled down to a one-kilogram [2.2-pound] CubeSat," says Colin McInnes from the University of Glasgow. "You can imagine a similar device in future weighing a gram [0.03 ounces]."

If we can pack the intricate payload of a modern space probe onto a chip the size of your thumbnail, then we'll have a really lightweight explorer ready to be dispatched to the stars. However, it wouldn't be fired by traditional rocket-based propulsion – that's simply too slow.

Instead, the Breakthrough Starshot team proposes firing pulses from a ground-based 100-gigawatt laser at sails strapped to a flotilla of micro-spacecraft. This should give each interplanetary spacecraft an almighty kick, accelerating them up to ten per cent of the speed of light. Send enough and a few survivors should make it to Alpha Centauri within a human lifetime. The onboard cameras could then send back those historic images of a distant alien solar system.

If it sounds simple, it isn't. "There are a number of engineering problems to solve," says Coates. Not least developing the 100-gigawatt laser required. There are safety concerns, too. "You'd have to worry about what a laser of that power would do to the atmosphere, or to aircraft or satellites orbiting above," says Coates. But McInnes believes there will come a time when technology converges and it will become feasible.

"We could well see with interstellar travel that someone puts advancing technology together in a novel way to create something new," he says. Doing so would also bring us greater knowledge of the environment between the stars – the interstellar medium – and kick-start a revolution in our understanding of this under-explored region of space.

Yet for many, the real dream of interstellar travel is not to dispatch tiny robots, but instead to send people to explore these far-off solar systems, just as early terrestrial explorers sailed vast oceans to conquer new continents. "There is no doubt that humans are more efficient explorers than robots," says Ian Crawford, a planetary scientist from Birkbeck, University of London. Yet we are currently about as far from travelling between the stars as you can get. We've barely dipped our toes into the vast cosmic waters and instead we remain largely in low-Earth orbit with only a dozen American men having left their footprints in the lunar dust.

As we've seen, the distances involved in interstellar travel are more than intimidating. If we are to cover them within a human lifetime, then we need to be able to accelerate people to at least ten per cent of the speed of light – something that brings with it a whole host of new challenges. "The real limiting factor is mass," says Crawford. The trouble with human missions is that we need food, water and oxygen to survive. Providing all of these things significantly ramps up the mass of the mission. To accelerate that mass you need fuel, which itself adds mass, requiring even more fuel. It's a vicious circle. "It becomes such a difficult problem that it would be irresponsible to argue that it is at all realistic," Crawford says.

But that's because in that scenario we're restricting ourselves to achieving the goal of a crewed interstellar mission in a single human lifetime. We could, instead, invoke a plan that is dear to science fiction writers: the generation ship. Instead of going fast we could go slow, meaning that much less energy is required to accelerate the craft. The consequence is that the mission would take far longer than a single human life span. "You'd have some large, self-containing colony in which generations [of humans] live out their lives and it is their descendants who reach the destination," Crawford says.

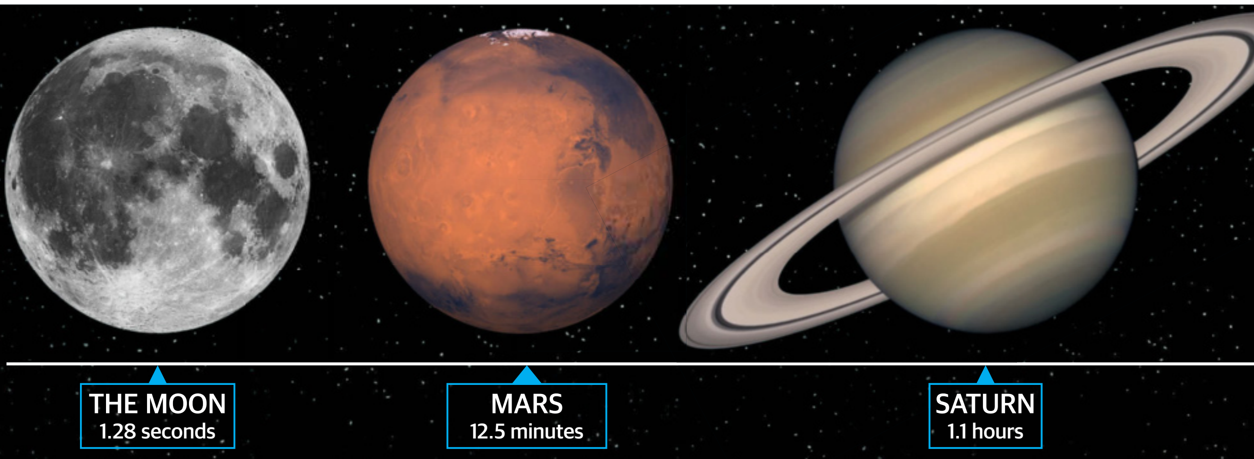
> "In 100 years' time, human hibernation may be possible, making it easier to send humans to the stars" **Ian Crawford**

Physicist Stephen Hawking has thrown his name behind the Breakthrough Starshot mission to get to Alpha Centauri

Travelling near the speed of light

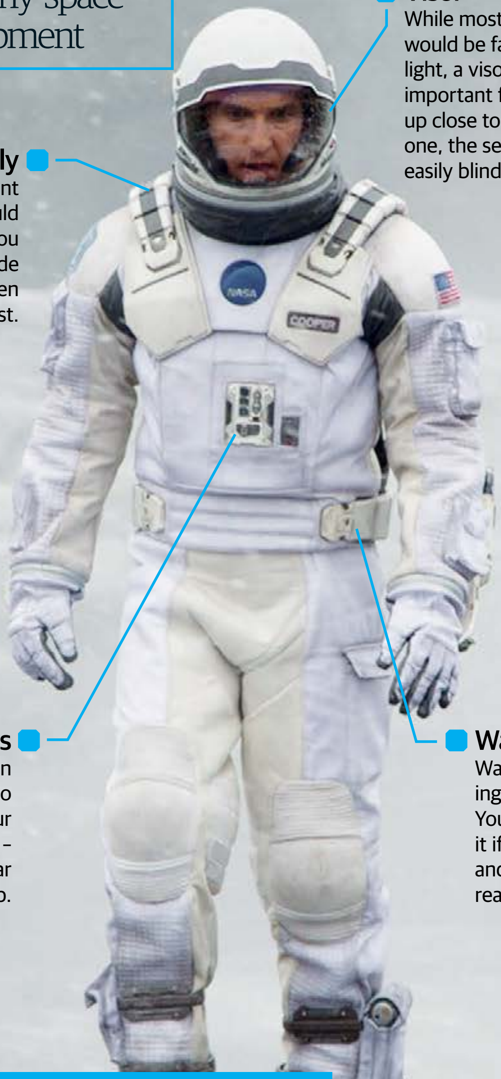
How long does it take light to travel through the universe?

NAME OF TARGET
Time it takes to get to target from Earth



THE SPACESUIT

A key part of any space traveller's equipment



Oxygen supply
While the environment inside your craft would have its own oxygen, if you needed to venture outside of your spaceship then breathable air is a must.

Visor
While most of the journey would be far from any bright light, a visor is nonetheless important for when you are up close to a star. Without one, the searing light could easily blind you.

Communications
When you're encased in a spacesuit, having radio communication with your fellow astronauts is key – especially as you're too far from Earth for quick help.

Water supply
Water is a key ingredient for life. You'll certainly need it if you're roving out and about once you reach your destination.

HOW INTERSTELLAR TRAVEL AFFECTS THE BODY

- Changes in gravity can affect bone mass
- Radiation from cosmic rays can cause radiation sickness
- Radiation can also cause cataracts
- Long-term isolation can cause psychological trauma

THE SPACECRAFT

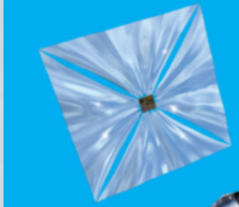
Scientists and science fiction writers have long dreamed up ways of travelling between the stars

Daedalus

In the 1970s, the British Interplanetary Society conducted research into a rocket that could travel between the stars. Their aim was to send their fusion-powered, 54,000-tonne spaceship to reach Barnard's Star (which is 5.9 light years away) in 50 years.

Project Orion

An idea from the 1950s and 1960s would have used controlled nuclear explosions to propel an interstellar craft. The difficulty was that many countries were (and still are) signed up to an international treaty banning the detonation of nuclear devices in space.

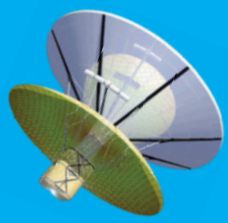


Breakthrough Starshot

The latest idea from Stephen Hawking and Yuri Milner is to send a swarm of tiny probes to the Alpha Centauri system by firing a powerful laser at sails strapped to the miniature machines.

Sänger Photon Rocket

Eugene Sänger suggested using antimatter as the propulsion mechanism for a spacecraft in the 1950s, as when antimatter collides with matter it creates energy that could propel the craft forwards.



Bussard Ramjet

One of the big problems with interstellar travel is the need to carry vast amounts of fuel. To get around this problem, a ramjet could theoretically use magnetic fields to scoop up interstellar material as it goes, which could then be used as fuel.

PLUTO
4.6 hours

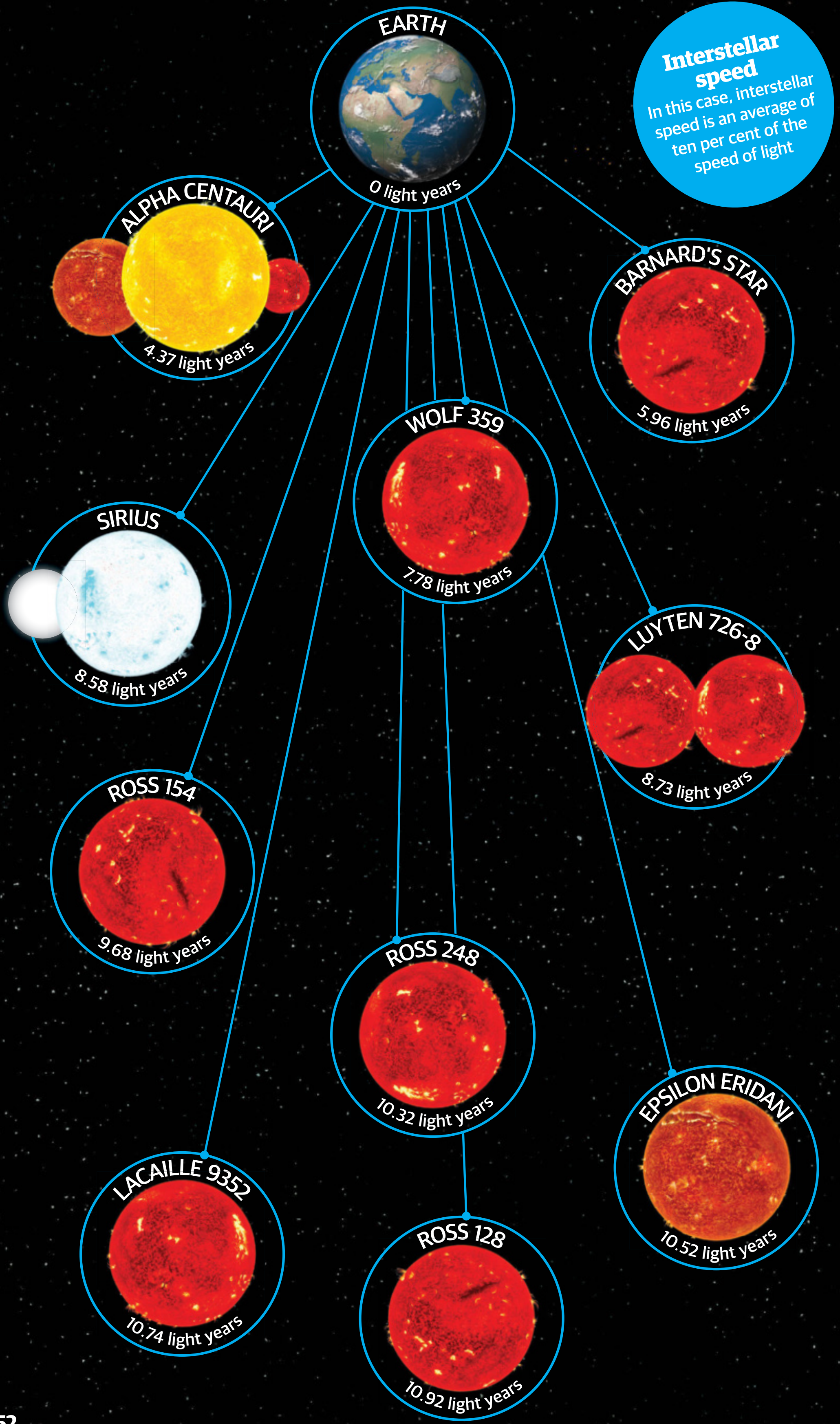
PROMIXA CENTAURI
4.2 years

CENTRE OF THE MILKY WAY
30,000 years

EDGE OF OBSERVABLE UNIVERSE
46.5 billion years

Interstellar road map

Given how difficult it is to travel far from the Earth, where might our interstellar travels take us?



Interstellar speed

In this case, interstellar speed is an average of ten per cent of the speed of light

THE LOCATIONS

Alpha Centauri

Distance from Earth: 4.37 light years
Current travel time: 30,000 years
Interstellar speed travel time: 43 years
This three-star system includes Proxima Centauri, which is the nearest star to Earth after the Sun. It is believed there may be planets around these stars.

Barnard's Star

Distance from Earth: 5.96 light years
Current travel time: 42,500 years
Interstellar speed travel time: 60 years
One of the fastest moving stars in the galaxy, this is also the closest star to Earth (after the Sun) that is visible from the Northern Hemisphere.

Wolf 359

Distance from Earth: 7.78 light years
Current travel time: 55,500 years
Interstellar speed travel time: 78 years
This red dwarf is located in the constellation of Leo and it can only be seen through a large telescope.

Sirius

Distance from Earth: 8.58 light years
Current travel time: 61,250 years
Interstellar speed travel time: 85 years
Sirius is the brightest star in the night sky as it is one of the closest to us. It is part of a double star system.

Luyten 726-8

Distance from Earth: 8.73 light years
Current travel time: 62,350 years
Interstellar speed travel time: 87 years
This star, seen in the constellation of Cetus, is actually a binary system of two stars encircling each other every 26.5 years or so.

Ross 154

Distance from Earth: 9.68 light years
Current travel time: 69,100 years
Interstellar speed travel time: 97 years
This star, found in the constellation of Sagittarius, can only been seen with apertures of 3" or larger.

Ross 248

Distance from Earth: 10.32 light years
Current travel time: 73,750 years
Interstellar speed travel time: 103 years
This small star in the constellation of Andromeda emits just 0.2 per cent of the Sun's light.

Epsilon Eridani

Distance from Earth: 10.52 light years
Current travel time: 75,000 years
Interstellar speed travel time: 105 years
This bright star, visible with the naked eye, has a confirmed planet orbiting around it and has been a popular interstellar travel target in science fiction.

Lacaille 9352

Distance from Earth: 10.74 light years
Current travel time: 76,700 years
Interstellar speed travel time: 107 years
Visible in the Southern Hemisphere with binoculars, this star is smaller and cooler than our Sun.

Ross 128

Distance from Earth: 10.92 light years
Current travel time: 78,000 years
Interstellar speed travel time: 109 years
Ross 128 is a red dwarf star whose orbit around the Milky Way will bring it closer to us in the future.

However, in order to maintain sufficient genetic diversity on board – to prevent too much inbreeding – studies have suggested you'd need an initial crew of between 75 and 150 people. Providing living quarters and supplies for the equivalent of a small hamlet for hundreds of years would require your ship to be enormous – kilometres long in Crawford's estimation.

"You face engineering challenges either way," he says. Either you have to build a small ship but struggle to get it up to the lofty speeds required for quick passage, or you have to struggle to build an enormous ship here in the Solar System that will carry hundreds of people for hundreds of years. The latter case is also particularly prone to ethical concerns. You'd be creating generations of humans 'imprisoned' on a craft with no memory of home and no hope of seeing the eventual destination.

Of course, this is all based on the assumption that a human lifespan is somewhere close to 100 years. What if that figure is only a product of the times we live in? After all, we're living twice as long on average than we did many centuries ago. Perhaps there is no upper limit to how long we can live. That's certainly the view of gerontologist Aubrey de Grey, who sees ageing as a disease that's curable like any other. He believes that the first person to live to 1,000 is alive today. A remarkable claim, but less so when you realise that he isn't talking about one miraculous boost in medical understanding to extend your life that far. Instead, one initial breakthrough could extend your life sufficiently so that you're always ahead of the medical curve, living ten years longer until another breakthrough occurs that will extend your life further. Then again, maybe he is wrong.

Given all these significant hurdles, it's no surprise that global space agencies, including the European Space Agency (ESA), are seriously looking into another alternative: human hibernation. ESA's Topical Team on the subject is tasked with determining "a probability based on current knowledge of controlled use of human hibernation being applicable to human spaceflight in a foreseeable future, and rough estimates on the timeline, potential showstoppers, and gains." If we could master such methods, the advantages are clear.

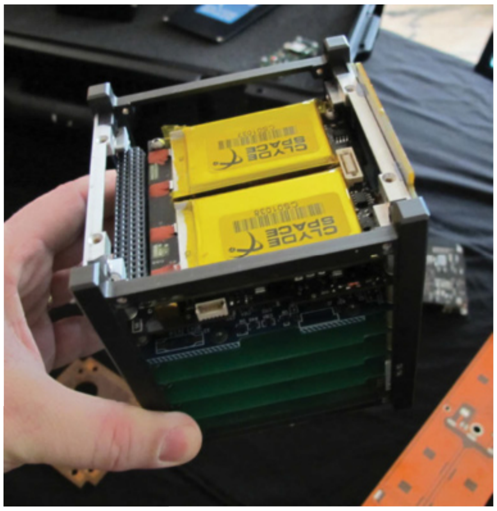
You'd need a much smaller crew, and reproduction on board would no longer be necessary. It's also better psychologically for those on board as they don't have to experience the rigours of the voyage. Plus, as they are inactive, they won't use as many resources, meaning the mass of the mission could be kept to a minimum. "It is very early days and no one knows if it is possible or not," says Crawford, "but it's not impossible to imagine that in 100 years' time, human hibernation may be possible, making it easier to send humans to the stars."

If we do make it to the stars, it would make astronaut (which means 'star-sailor') a more accurate term for our space travellers. The challenges are great but, like all successful endeavours in human history, you can't achieve something unless you set yourself a goal. It is almost certain that robots will go before us, as they did in the early days of space exploration. But, one day, it might just be possible that your descendants will gaze upon the continents, clouds and oceans of a familiar yet far-off world and be the first to set up a human outpost among the stars.

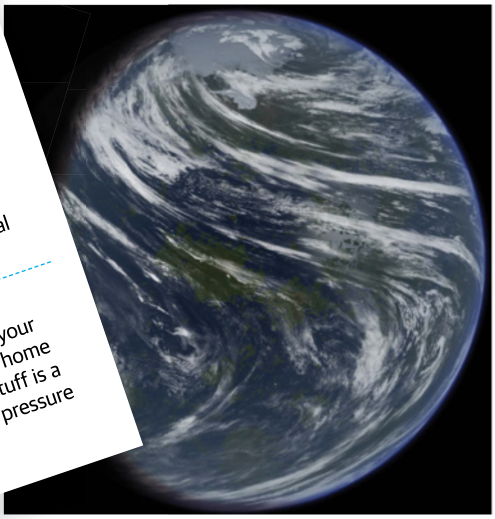
We already fire laser beams at the Moon, but for star sailing they would have to be a lot more powerful

Aubrey de Grey believes the first person to live to 1,000 is alive today, a boost to the idea of interstellar travel if true

Satellites are already being significantly miniaturised. This CubeSat is just 10cm (3.9in) long on each side



Travellers to other solar systems may find a planet similar to ours but with different shaped landmasses



Requirements for interstellar travel

20:20 vision (or ability to correct to it)
Good eyesight is crucial for the wide range of intricate activities required for an interstellar astronaut.

Fit and healthy (blood pressure: 140/90)
Far from home without the ability to return to Earth quickly for medical attention, overall health is key.

Psychologically strong
Being isolated and cut off from your home planet with no easy way home is difficult – the right mental stuff is a must. Remaining calm under pressure is also vital.

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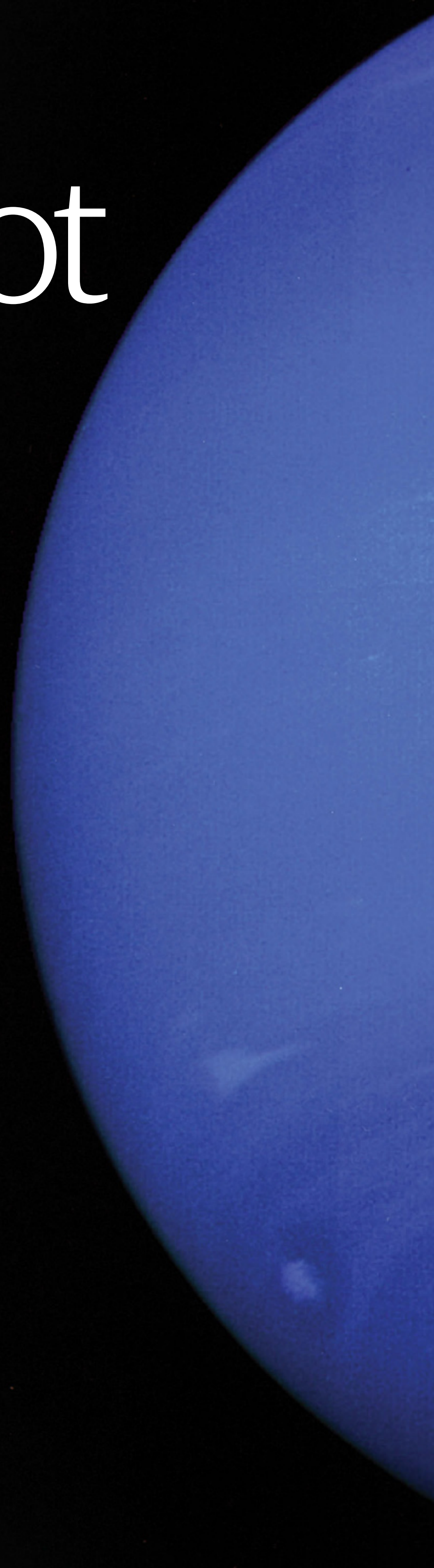
Neptune's new dark spot

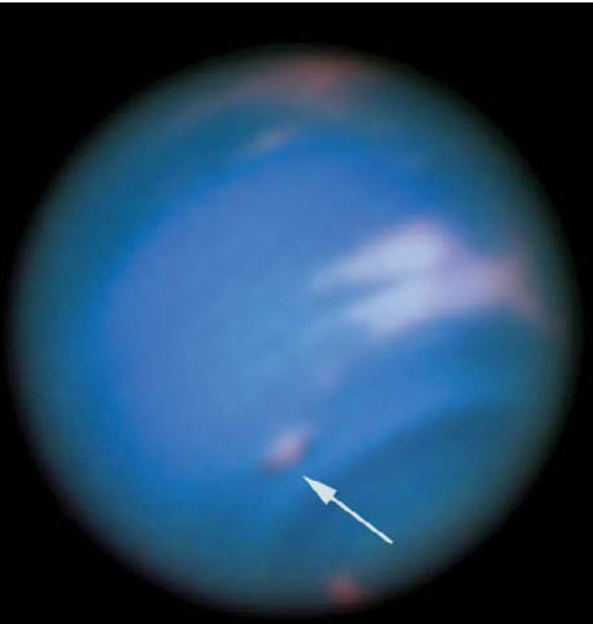
Atmospheric bright clouds confirm a murky vortex on the ice giant

New images snapped by NASA's Hubble Space Telescope have confirmed that a dark, violent vortex on Neptune does indeed exist in the atmosphere of the ice giant. This isn't the first time these features have been spotted raging on the planet's tempestuous surface either - the Voyager 2 spacecraft first discovered them when it made a flyby back in 1989.

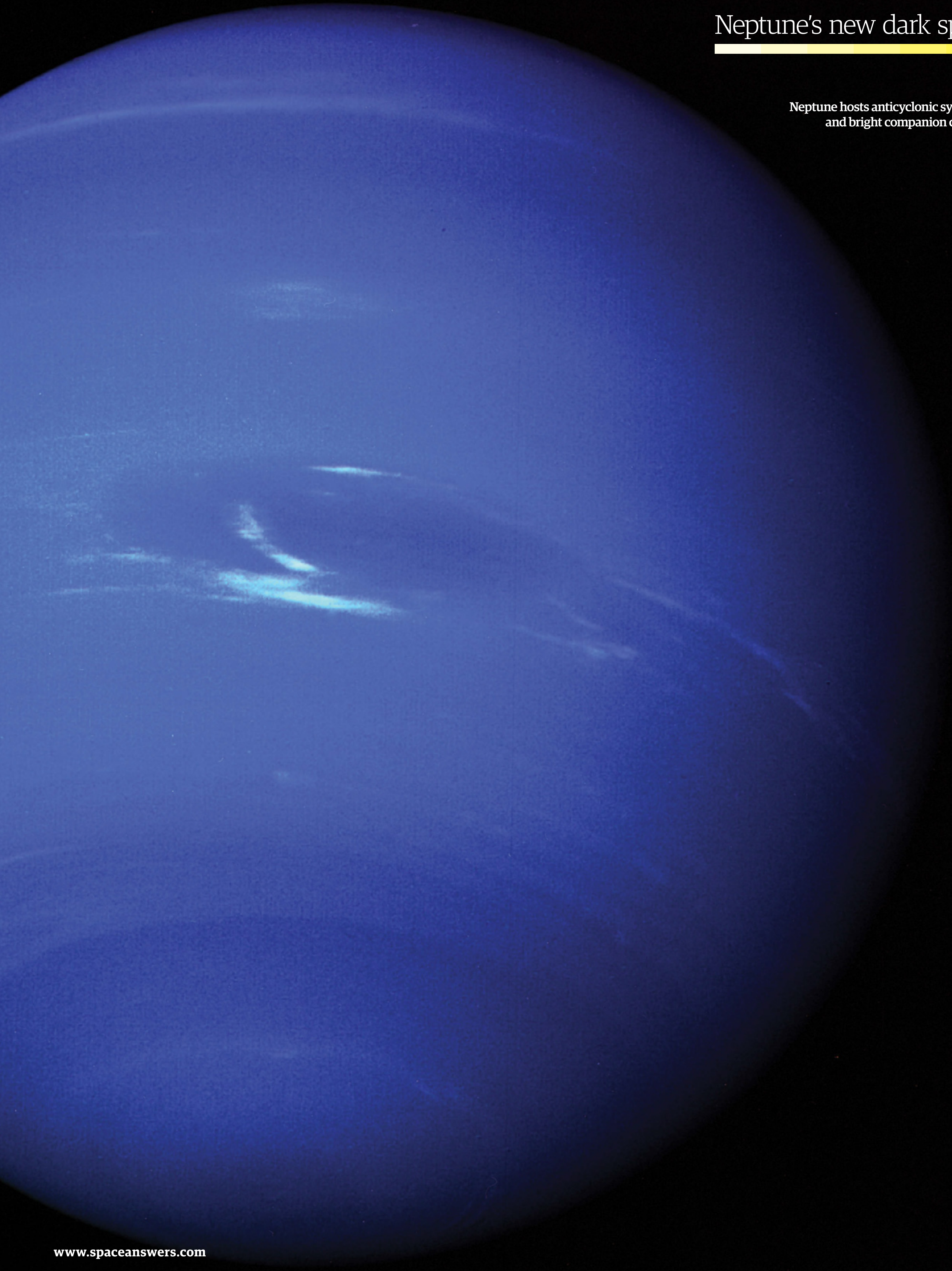
Neptune's dark vortices are systems of high pressure and are usually accompanied by bright clouds, which are made when air is perturbed and diverted upward over the dark vortex, causing gases to freeze into methane ice crystals - they are similar to the pancake clouds that linger above the clouds here on Earth. The ice giant's dark vortices have been impressively diverse over the years, exhibiting a range of different shapes and sizes.

Compared to the anticyclones commonly found on gas giant Jupiter, Neptune's dark vortices are somewhat short-lived - despite this though, astronomers can work out the structure and dynamics of the giant's atmosphere.





NASA's Hubble Space Telescope confirmed a long-suspected dark vortex in the ice giant's atmosphere



Neptune hosts anticyclonic systems
and bright companion clouds

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YOUR QUESTIONS ANSWERED BY OUR EXPERTS

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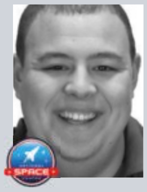
Sophie Allan

National Space Academy Education Officer
Sophie studied astrophysics at university. She has a special interest in astrobiology and planetary science.

Josh Barker



Education Team Presenter
Having earned a master's in physics and astrophysics, Josh continues to pursue his interest in space at the National Space Centre.

Gemma Lavender

Editor
Gemma holds a master's degree in astrophysics, is a Fellow of the Royal Astronomical Society and an Associate Member of the Institute of Physics.

Robin Hague

Science Writer
Robin has a degree in physics with space technology and a master's in hybrid rocket engine design. He contributes regularly to All About Space.

Tamela Maciel

Space Communications Manager
Tamela has a degree in astrophysics and writes for the National Space Centre Blog. She has eight years experience in science communication.

Planet 9 is an icy giant suspected to reside far out beyond the orbits of Neptune and Pluto

SPACE EXPLORATION

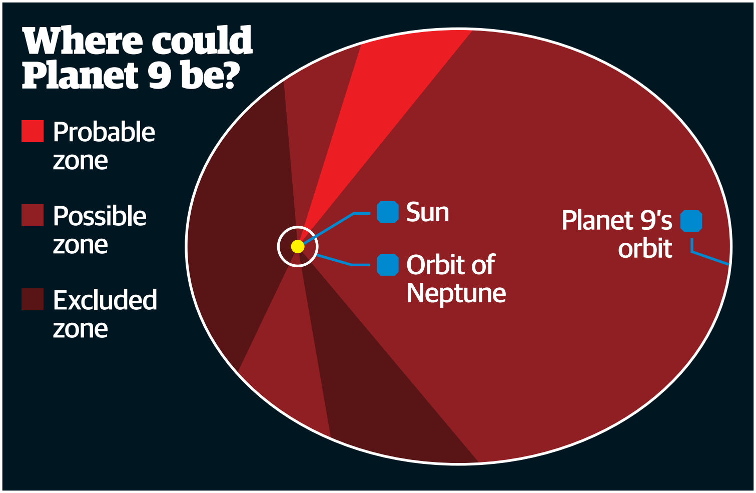
Will we ever send a mission to Planet 9?

Nigel Bennett

We need to confirm the existence of Planet 9 first. This hypothetical ice giant was put forward as an explanation for the similar orbital configurations of six distant objects beyond the orbit of Neptune.

Located beyond the orbit of Pluto, the mysterious ice giant is regarded as being in interstellar space. Given that a spacecraft would be out of the influence of the Sun, using a craft with solar panels would be difficult. A craft similar to New Horizons, which operates on a radioisotope, may be a solution for powering instruments to Planet 9 in order to study the world up close. **SA**

Where could Planet 9 be?



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The Sci-fi film, *The Martian*, was released in 2015 and was directed by Ridley Scott

SOLAR SYSTEM

How realistic is the film, *The Martian?*

Katherine Matson

The Martian is celebrated as one of the most accurate science fiction films ever released. Many elements of the film have had a lot of thought put into them. With the exception of a few small tweaks for cinema, it generally holds up to scientific scrutiny and gives a good representation of what a trip to Mars could involve.

The biggest issue of the whole film is the storm that kicks off the story. While it is true that you can get high-speed winds on Mars that are in excess of 95 kilometres (60 miles) per hour, the atmosphere is incredibly low density. With a density around one per cent that of Earth's, even a 160-kilometre (100-mile) per hour wind on Mars would be equivalent to a 16-kilometre (10-mile) per hour wind down here on Earth. Enough to fly a kite, but probably not enough to blow an astronaut away! **JB**

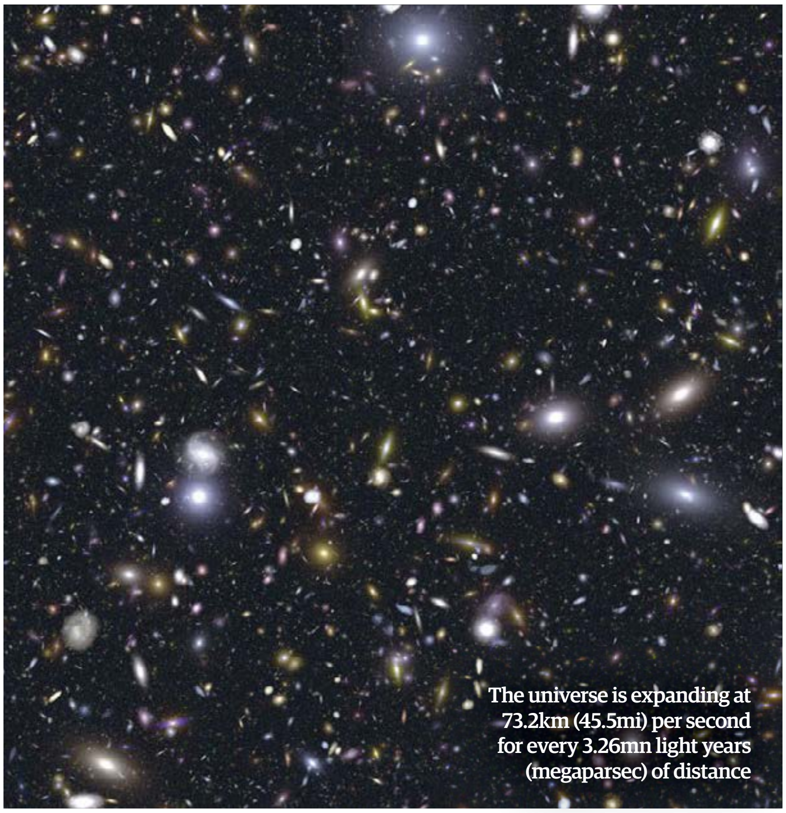
DEEP SPACE

How did we work out that the universe is expanding faster than we thought?

Joanna Burns

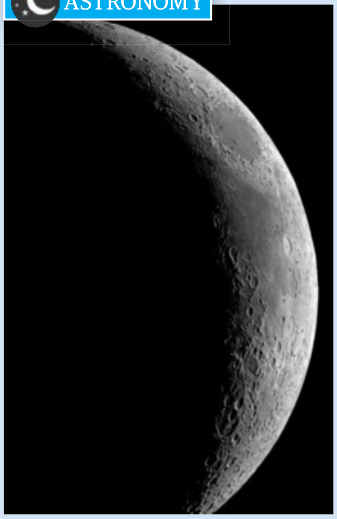
Recently, a team of 15 scientists used the Hubble telescope to analyse the movements of 2,500 stars, achieving the most precise measurements of star movement ever taken. From this, they were able to calculate that the universe is expanding at a rate of 73.2 kilometres (45.5 miles) per second for every megaparsec (which is 3.26 million light years) of distance.

That's a touch faster than previous measurements of the universe's speed, determined from the cosmic microwave background - the relic radiation of the birth of the universe. The reason for this faster rate is unknown, but understanding this change is the next big challenge. **JB**



The universe is expanding at 73.2km (45.5mi) per second for every 3.26mn light years (megaparsec) of distance

ASTRONOMY



The Moon, with its many craters and lunar seas, is an ideal target for novice astrophotographers

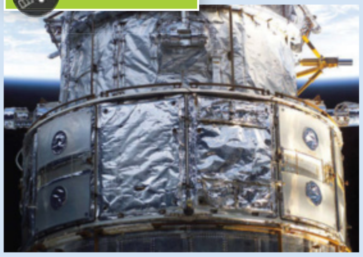
What is a good first target for astrophotography?

Brian Neville

A good first target for astrophotography would probably be one that you can easily find and identify, such as the Moon or the naked eye planets. While working on something like astrophotography, it's handy to keep the other elements such as telescope pointing rather simple. So choose something that is easy to find and track.

For more specific targets, something that contains a lot of detail can be useful to help dial in your camera and settings. A popular first target is something like the Great Orion Nebula (M42). This is visible to the naked eye, so is easy to find and in a popular constellation. It also contains a lot of extra detail that you can slowly reveal as you get more comfortable with your setup. Other popular choices involve many star clusters, nebulae and even the Andromeda Galaxy. **JB**

DEEP SPACE


Due to the freezing temperatures of the universe, spacecraft are insulated

How quickly do objects freeze in space?

Tim Harrison

A very rough calculation gives the average human body about six or seven hours before it freezes once exposed to space. As slow and as potentially painful as that would be, don't worry about it too much. If you were exposed to the vacuum of space you would only be conscious for around 15 to 20 seconds before you passed out due to the lack of oxygen. A few minutes after that, you would meet your demise.

In terms of other objects and the time it would take them, it depends entirely on their ability to hold onto heat. They would generally take a little longer to freeze compared to similar temperatures on Earth. This is because in the vacuum of space there is much less heat loss through conduction and convection. **JB**

Scientists use the collisions of binary stars to measure the vast distances of space

DEEP SPACE

What would happen if two stars collided?

Gerald Wells

There would be quite an explosion! The most common types of collisions occur between binary stars. The two orbiting stars can spiral in towards each other over time, until the larger star begins to pull off the outer layers of the smaller star. This transfer of material grows the larger star and pulls the smaller star closer. What happens next depends on the size of the stars.

The two stars can merge into one bigger star, which begins a whole new life cycle; or if one of the stars is very massive, then the collision can trigger an enormous explosion known as a supernova, which leaves behind a dense core of either a neutron star or a black hole. Collisions like these are beacons that help astronomers measure the vast distances in space.

Space is huge; even within a galaxy, the distance between individual stars is so large that they rarely have a direct collision - a good thing for the planets around them! **TM**

SPACE EXPLORATION

What is the secret X-37B space plane doing?

Paul Johnson

Unfortunately, not many people know exactly what this space plane is up to. What we do know is that the X-37B space plane is a former NASA mission that was transferred to the US Department of Defense.

Operated by the United States Air Force, its official mission is to demonstrate reusable space technologies. As a Department of Defense project, many of the precise details regarding the X-37B's missions are kept secret, leading to rampant speculation on what the spacecraft is actually up to.

Many of these claims are refuted and the emphasis on testing new space technologies has been reiterated. The latest mission was designed to test a brand new propulsion system.

This system, called the Hall effect thruster, uses high-speed electrons to generate incredibly efficient thrust that could propel a craft forwards. This new system could revolutionise long-distance space missions. **SA**

The exact details of X-37B's mission are largely unknown as it is under the control of the US Department of Defense

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SPACE EXPLORATION

How can I become an astronaut?

Tom Watson

1 Study hard

Astronauts need to be very academically capable, so make sure that you study hard at school and get good grades. If you've already finished education, you may find that you'll need to brush up on your science and space knowledge.

2 Earn a degree

Almost all modern astronauts need a university degree or equivalent in a relevant field. This can be Natural Sciences (physics, biology, chemistry or mathematics), Engineering or Medicine. Studying aeronautics or astronautics as well will help.

3 Get some experience

ESA looks for astronauts between the ages of 27 and 37 but for NASA it's a bit broader, from 26 to 46. You'll need at least three years of experience in a related postgraduate professional experience or, alternatively, extensive flying experience as a pilot.

4 Learn a language

It is imperative when applying for NASA or ESA to be fluent in English. It is also useful to know another foreign language, with Russian being the preferred choice as it is the second official language on the International Space Station.

5 Be healthy and fit

Being an astronaut is tough both mentally and physically. NASA and ESA look for healthy and fit astronauts with 20/20 vision. You'll need to pass a medical examination to qualify, but over-developed muscles may be a disadvantage for weightlessness.

6 Send your application

Now you're ready, keep an eye out for astronaut openings. NASA typically selects 20 astronauts every two years, but for ESA it's much rarer as they have less flying opportunities. If you're a non-US citizen, you'll need to get dual citizenship to apply for NASA.

7 Get through screening

If your application is accepted, you're certainly not home and dry yet. You'll be among thousands of other successful astronauts who will be whittled down to a select few during a process of interviews, medical exams and orientation.

8 Ensure you specialise

For each three-man team on the ISS, their skills must ensure they are capable in all areas. So decide what you want to specialise in; you could become a mission specialist or a pilot, but for the latter you'll need over 1,000 hours of flying experience.

9 Be patient

Even at this stage, you're still not guaranteed a flight in space. You'll need to set yourself out from the crowd to try and get selected for an upcoming mission, but the wait could be several years. Be patient, your flight should come eventually!

10 Get ready for launch

So you've passed the training, specialised and now you've been assigned a flight. If you apply before 2020 it's likely you'll be going to the ISS, but after that you could be one of the pioneers in the next generation of space travel beyond Earth orbit.

What are the planets like on the inside?

Even among the worlds of our own Solar System we see a huge variety of planetary composition

Diane Jones

The terrestrial planets, Mercury, Venus, Earth and Mars, are separated out into similar layers – a hot dense core, a warm pliable mantle and a cooled rocky crust. Mercury, closest to the Sun, is around 70 per cent metallic and 30 per cent rocky. Its core is thought to comprise as much as 85 per cent of the planet, a liquid heart of iron 4,000 kilometres (2,485 miles) in diameter. This is covered by 600 kilometres (373 miles) of silicon rich mantle and between 100 to 200 kilometres (62 to 124 miles) of rocky crust.

Venus, similar in size and position to Earth, was expected to have a similar structure, but Venus has little magnetic field. Earth's field is created by rotation and convection in our molten core; Venus does seem to have a molten core, but for some reason it does not circulate in the same way. One possibility is that Venus' crust doesn't get recycled like Earth's does, so the whole core may be of uniform temperature, as heat is not escaping to the surface.

Fortunately for us, Earth has a significant magnetic field that protects us from solar radiation; but our core is not just liquid. The pressure at the centre of Earth is sufficient that the iron collected there becomes solid, despite the temperature being around 6,000 degrees Celsius (10,832 degrees Fahrenheit). This has been determined by studying the way seismic waves travel through the Earth. The solid inner core is around 1,220 kilometres (760 miles) in diameter. This is surrounded by a liquid core that is 2,200 kilometres (1,367 miles) deep, which is then topped by 2,900 kilometres (1,802 miles) of mantle and an average crust of 35 kilometres (22 miles).

Mars is also differentiated into layers, with a liquid core, a mantle – that appears to have driven volcanoes in the past – and a rocky crust. Like Venus, there must not be convection in the core, as Mars has no magnetic field.

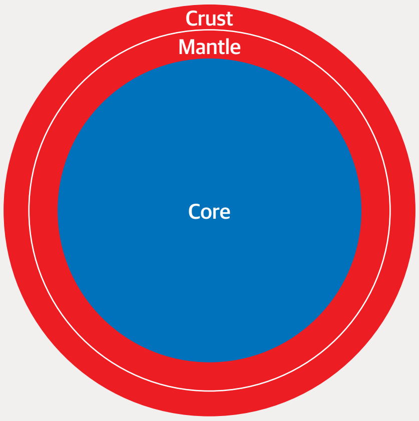
Jupiter is the first of the gaseous planets and the largest in the Solar System; with gas giants, there is no sharp dividing line between the planet and its atmosphere. It is thought that Jupiter has a dense core, possibly rocky, surrounded by 'metallic' hydrogen. This is a strange condition predicted to occur under huge pressures, where hydrogen behaves like a dense electrically conductive substance. This layer is thought to cover 78 per cent of the thickness of the planet and it is thought that above this, normal liquid hydrogen smoothly fades into the gaseous hydrogen atmosphere. Saturn is thought to be similar to Jupiter, with a rocky or icy core surrounded by the same types of hydrogen layers.

Uranus and Neptune are called the ice giants, not because they have ice in the sense we know, but because a layer of mixed methane, water and ammonia surrounds their rocky cores – equivalent to the mantle in terrestrial planets. These molecules are referred to as ices, though they form a hot dense liquid near the core and fade out into the atmosphere without a defined surface. **RH**

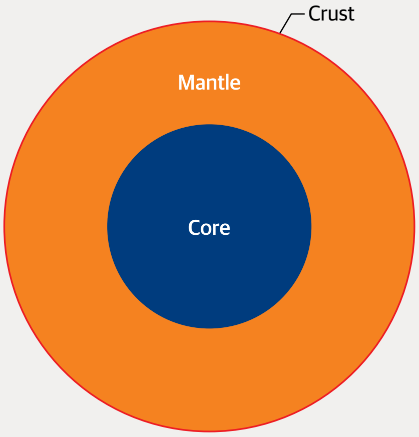
Under the surface

🟥 Rock
🟧 Molten rock
🟦 Ice
🟦 Molten iron
🟦 Iron
🟩 Liquid metallic hydrogen
🟩 Hydrogen gas
🟨 Atmosphere

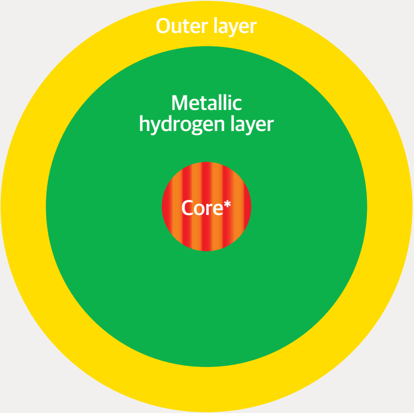
MERCURY



VENUS

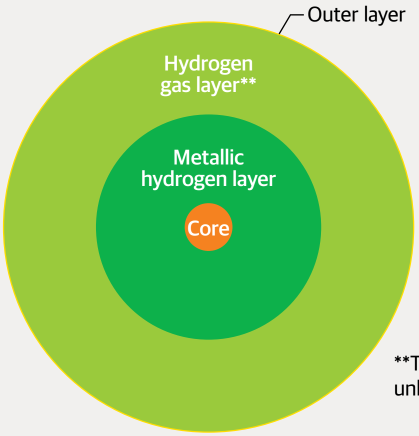


JUPITER

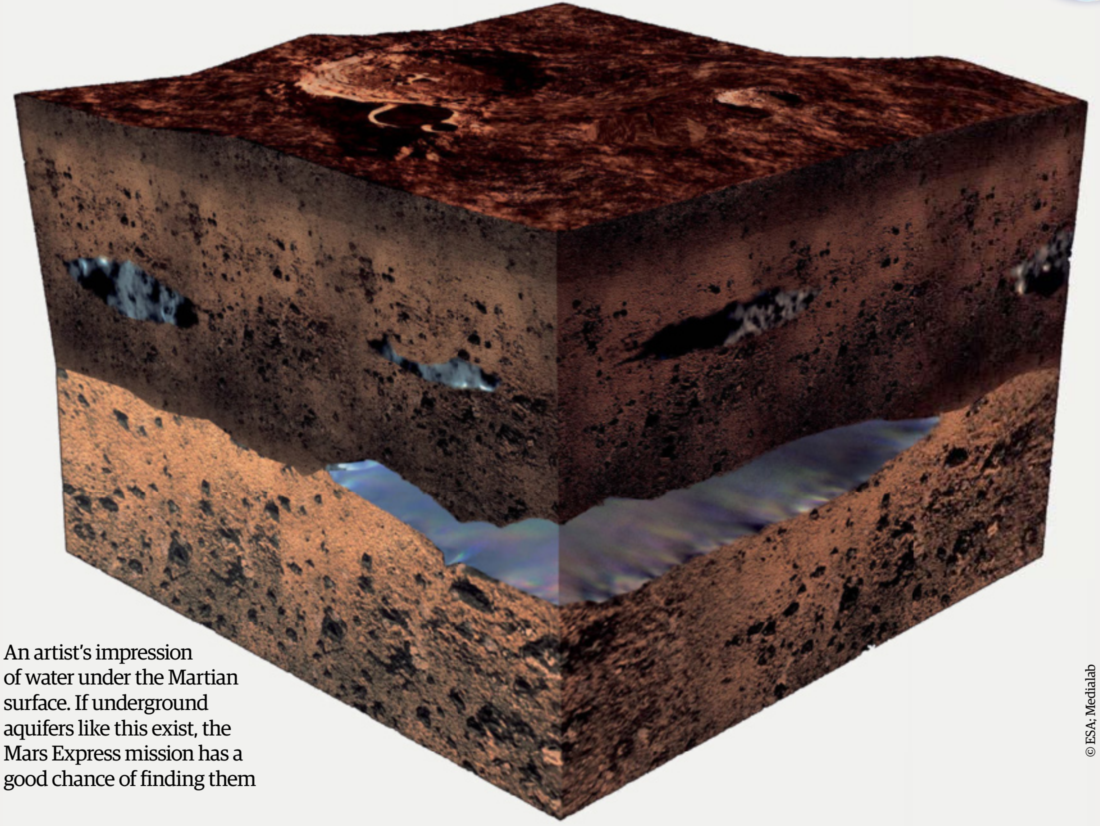


*Jupiter's core remains a mystery to scientists, but it is hoped that the Juno mission will shed some light on its size and composition

SATURN



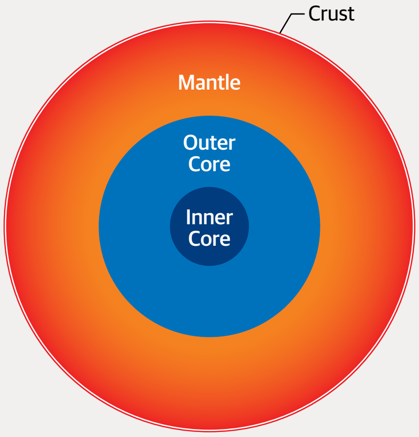
**Thickness unknown



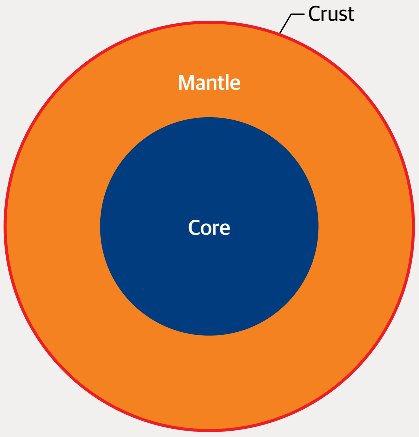
An artist's impression of water under the Martian surface. If underground aquifers like this exist, the Mars Express mission has a good chance of finding them

© ESA; Medialab

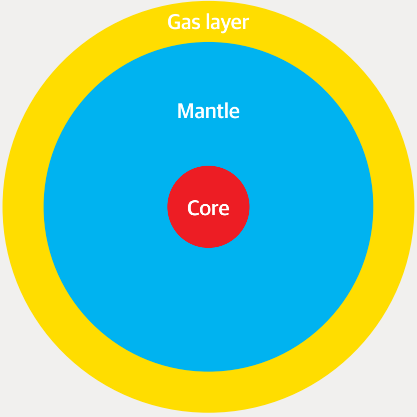
EARTH



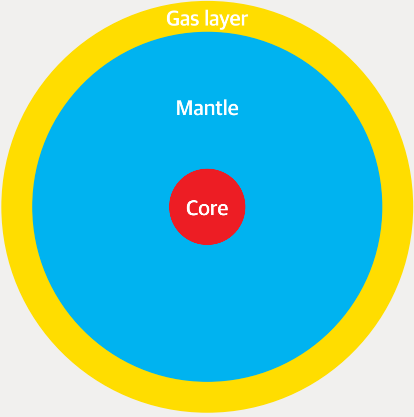
MARS

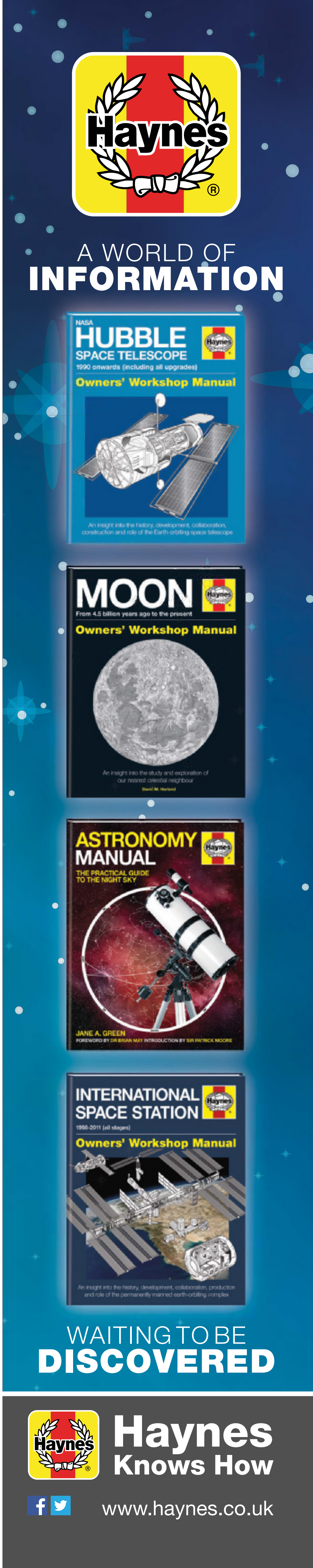


URANUS



NEPTUNE

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The universe at the IMAX

Hollywood film director Toni Myers has been making stunning documentaries for 45 years, turning many astronauts into big screen movie stars

Interviewed by David Crookes

You've been making movie documentaries for IMAX since 1971. When did you realise it was the perfect medium to tell stories about space?
I've always been attracted to the whole experience of breaking new experimental ground in cinema and I've been working for IMAX since its invention. I have the belief that the big IMAX screen can provide the next best feeling to being somewhere special, so we released our first space film in 1982 about the maiden voyage of the first space shuttle, Columbia, and we made *The Dream Is Alive* in 1985 about the fifth Challenger mission. But it was Graeme Ferguson, who co-invented IMAX, who founded the space unit. He's very much our emeritus.

> "The IMAX films take ordinary people like you and me into space and let them experience zero gravity"

CHANGE YOUR VIEW OF OUR UNIVERSE
IMAX
HUBBLE 3D
NARRATED BY LEONARDO DiCAPRIO
IMAX.COM/HUBBLE
IMAX
Myers directed and co-wrote the IMAX film *Hubble 3D* in 2010, which grossed $70mn (£52.3mn) in the box office

Have you been involved in every space-themed IMAX documentary?
All of the early films involved me as writer and editor but I started co-producing in 1997 when we made the film *Mission To Mir*. You'll see that Graeme Ferguson is credited on the film as a producer too, but he then retired. So the first film I directed was *Space Station 3D* in 2002 and I've done that ever since [Myers also wrote *Space Station 3D*, which starred Tom Cruise and was the first live-action film to be shot in space].

For many of your films, you have worked with NASA. Is the agency enthusiastic about getting its work on the big screen?
Oh yes. All of the astronauts agree that IMAX is a truly experiential immersive cinema experience. The films are a way to take ordinary people like you and me into space and let them experience zero gravity and float up to the window and see what they see. So, yes, we can watch this kind of thing on YouTube and Vimeo on an iPhone or computer screen but that does not give you the experience. IMAX more than fills your field of view and puts you right in the picture. Even conventional cinema doesn't do that.

Do you come up with the ideas for the films or is it very much a collaboration with NASA?
Mainly I make the proposal to NASA. The only one that they came to us with was *Mission To Mir*. NASA wanted to see whether it could work with the Russian space agency and its different cultures and different languages and so all that was necessary in building a complex structure in space. NASA flew a series of dockings and they came to us to ask if we could document them. So we flew our cameras and did that, and midway through they said, "We should make it into a film." It would have been nice to have known that at the outset but anyway, we made that into a film. But every other film has come about by our proposal to them. We're not looking at a general topic of space. We want a very specific focus.

In order to make your movies, you ask the astronauts to do the filming for you. What are they like to work with?
They're wonderful. I hesitate to say we have been lucky because that implies that there are some astronauts who are difficult to work with and I don't think that's the case: I haven't met one I didn't like or love working with. They're extremely dedicated and our projects are a break for them from the dryness of a lot of the technical tasks that they have to perform. Although we can't impinge on their daily schedules, they enjoy filming for us in their spare time, on Sundays and evenings, and they do it willingly. The idea of making a movie is kind of fun for them.

Do you have to train the astronauts?
We train them for an average of 25 to 30 hours if we can get it. We look at how they can be directors

INTERVIEW BIO

Toni Myers

Toni Myers is a Hollywood film director who has specialised in making movies for the biggest of screens – the IMAX – since 1971. Born in Toronto, she has written, edited, produced and directed a host of stunning space-related documentaries including *Blue Planet* in 1990, *Mission To Mir* in 1997 and *Space Station 3D* in 2002. *Hubble 3D*, which she directed in 2010, grossed $70 million (£52.3 million) and her latest 3D film, *A Beautiful Planet*, has been critically acclaimed. Narrated by actress Jennifer Lawrence and focusing on Earth, it was produced in cooperation with NASA and contains breathtaking footage of our planet, which was filmed by astronauts onboard the ISS using 4K digital cameras.

and cameramen and that gets their creative juices flowing. They are very creative people! A lot of engineers think they'll never be able to do it and while I know engineers take protective measures for astronauts screwing something up, they don't need to. Astronauts are the smartest people in the world.

How do the training sessions run?

They are spread over a few weeks so you don't do it all at once. Our astronaut training manager, James Neihouse, teaches them all the button-pushing but they're already trained on NASA's still cameras and there are a lot of similarities with the equipment. In the old days, we would have to train astronauts to load and unload magazines in a black bag and that was a little more challenging. I train them more in the aesthetics of movie-making; how they can direct their crew mates in scenes and how they should try and shoot candid activities. We look at the lengths of scenes and suggestions for how they might move the camera and think in 3D. We show them old IMAX films on an IMAX screen and we have a specialist sound recording trainer who comes in and tells them all about recording sound, including effects and how to mic. That's a very important part of it.

Do they get a dry run at it?

The last thing we do as part of their training is let them loose with the cameras and they get to make their own test movie inside a simulator. They have to light and direct the scenes and record the sound. We then put it up on an IMAX screen and there's nothing better than that. If the penny hasn't dropped before, it sure does when you see what you've done on a 15 by 24 metre [50 by 80 foot] screen. And it's hardly ever out of focus, I should add. If there are mistakes, they learn from them.

To what extent do you dictate the scenes you want to include in your movies?

The astronauts bring their own ideas to the films. While we're training, I start off with a list of scenes that I have made up that go with the theme of the movie, but I encourage their input to that because they're the ones who are going there. They know a ton of stuff I don't know. And, of course, we always tell them that if an alien comes up and puts its face in the window to film it - don't ignore it because it's not on the shot list. We tell them that they're the directors up there, not us.

With some of the films you've made, you have very much focused on Space Shuttle missions. Do they lend themselves better to a documentary?

Well, it's hard to make any film without human content in it so, yes, you can make a film about the planets or Solar System science, but without any human beings, it gets pretty dry pretty fast. Our audience is aged three to 103, so we have to cover a wide spectrum and I think people relate to

NASA's Terry Virts and ESA's Samantha Cristoforetti smiling after cutting her hair onboard the ISS

A scene from *A Beautiful Planet* showing the vivid colours of the reefs in the Bahamas

Behind the scenes of *A Beautiful Planet* during an IMAX camera training session at NASA's Johnson Space Center

> “The idea of *A Beautiful Planet* was to see the ISS as a metaphor for Earth in that both are closed life support systems”

themselves. I think that if you just do visualisations, you could probably do a short film with beautiful music but if you want to tell a story, you need people. You need a dramatic art and there has to be some kind of resolution.

In *A Beautiful Planet* you’ve got Jennifer Lawrence narrating and the movie is centred on ESA astronaut Samantha Cristoforetti. Why did you pick these people in particular?

It wasn’t necessarily my intention to make a female-focused film. I certainly wanted a female narrator because I just thought the dynamic range of a female voice was right for the topic, but that’s just an artistic choice. But I had no idea until really we started training Samantha what an amazing person she was.

What I do with the astronauts is talk to them after their flights, just for the tape-recorder, and record their recollections and impressions of their recent space flight. That’s when Samantha just totally shone. Those things she says in the film are entirely her own words. She was so eloquent, she said things that sort of encapsulated the whole reason for making the film, things that I could never have written so well.

At the same time, you’re focusing on the planet as well as the mission…

Well yes, the whole idea of the film was to see the ISS as a metaphor for the whole planet in that both are closed life support systems. As soon as you take away human beings they can’t survive. The only difference between them is that Earth doesn’t get any re-supply like they do on the ISS. That’s sort of the implied message of the film.

Do you communicate with the astronauts during the missions?

We do and this is an improvement over previous films. We can communicate by email as long as we follow certain ground rules. First, if you’re allowed communication privileges, you have to go through the system and you definitely can’t ask them to do something that would impinge on their regular duties. You can’t be requesting things that you haven’t formally requested before – all of that has to be negotiated.

But if they’re wondering about something, they can call me using their mobile phone. So they’d be thinking, “What if I shot this kind of scene? We never really discussed that, maybe I’ll call Toni and ask what she thinks.” They’d just call me up and we can discuss the pros and cons and either me or James can give them advice.

Were you able to see footage while they were still on the ISS?

Yes. We might say, “Okay, go ahead and try that and send it down to us,” because it would only take a couple of days. We would get it in the cutting room and look at it and then I could send them back a little PowerPoint of screengrabs with what they’d actually shot and with annotated notes on it, saying: “Do this, don’t do that, this was too high, this was too close.” In the old days we would have to wait until the shuttle mission was over and the astronauts had landed. The footage would have to be flown from Kennedy Space Center to Los Angeles and then processed and developed, and by the time we received the footage, it was three to four weeks later.

So it’s much better with the 4K digital cameras?

The footage goes to the Johnson Space Center and it’s put on a secure site for me to pull down. It works well. NASA also said we had to go digital because 70mm film is very bulky. We tested half a dozen cameras, different makes of commercial cameras, side by side, and we chose the Canons because they outpaced every other one, for our purposes anyway.

Do you ever wish you could get up there yourself and film?

Oh yes, absolutely, I would go within a minute. I’d be very happy to go but you need a few PhDs and you need to be fit, neither of which I am known for. So no, it wasn’t on the cards for me. But I’ve had dreams in zero gravity and I feel like I’ve been there. I’ve certainly spent a lot of time staring at the insides and outsides of space missions.

Are you working on anything at the moment?

No, I’m working on my retirement at the moment. I don’t know how that will go but it’s an experiment. I’ve been making movies for 45 years and I have grandchildren now, and while I’m not saying never, I’m taking a bit of a long rest.

So if NASA approached you tomorrow with an idea, what do you think you’d say?

It would depend on what it was. *Space Station 3D*, *Hubble 3D* and *A Beautiful Planet* were all films that I really wanted to make and the inspiration and the desire came from us, not NASA. So it’s about finding something interesting. You don’t want to embark on something unless you’re pretty sure that it’s a good story to tell.

Does virtual reality interest you as a film-maker?

Yes, but I haven’t seen enough of it. IMAX is certainly going in that direction but what I’ve seen of VR is very low resolution. I just don’t know enough about how you tell a story in that medium. It certainly has a way to go to look anything as good as IMAX and I also feel it’s a lonely pursuit. It’s not easy to share VR with anybody. Some of the best things about the cinema are being able to grab onto your boyfriend or whatever, or take your kids, and have a communal experience. These things will be overcome, I guess.

To watch *A Beautiful Planet,* check for showings at your local IMAX in the UK and the US.

A scene from the IMAX film *A Beautiful Planet* showing the entire northeast of Canada, the United States and beyond as seen from the International Space Station

ESA astronaut Samantha Cristoforetti and NASA Commander Terry Virts during an IMAX camera training session at NASA’s Space Station Mock-up and Training Facility

ESA astronaut Samantha Cristoforetti rests in a chair outside the Soyuz TMA-15M just minutes after landing in a remote area near Zhezkazgan, Kazakhstan on 11 June 2015

NASA Commander Barry (Butch) Wilmore shoots a scene with the IMAX camera through the window of the ISS’s Cupola Observation Module in *A Beautiful Planet*

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GUIDES AND ADVICE TO GET STARTED IN AMATEUR ASTRONOMY

What's in the sky?

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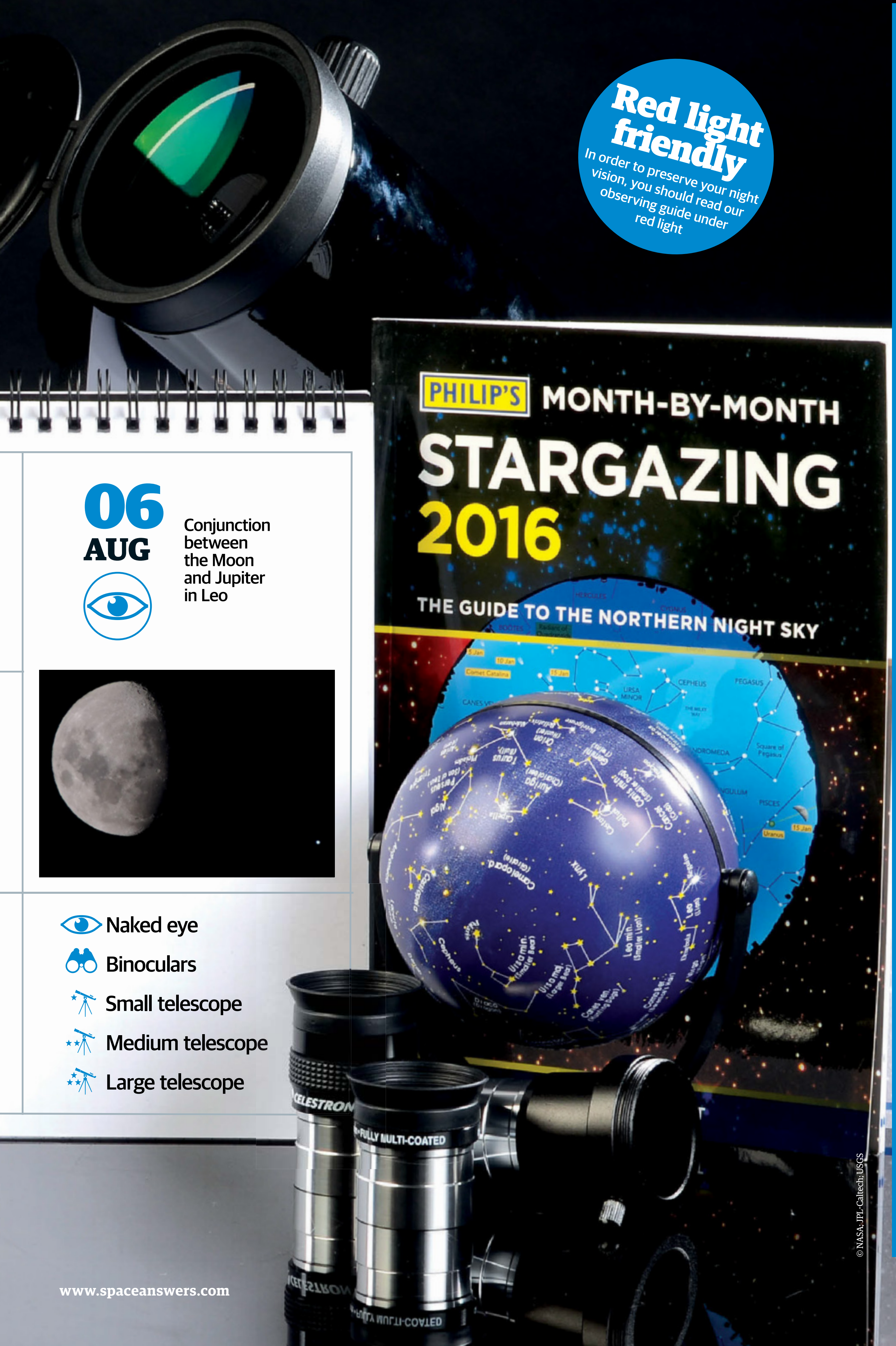
26 JUL
Conjunction between the Moon and Uranus in Pisces

29 JUL
δ-Aquarids reach their peak at 20 meteors per hour

12 AUG
Conjunction between the Moon and Saturn in Ophiuchus

13 AUG
Perseids reach their peak at 80 meteors per hour

16 AUG
Mercury at greatest elongation east in the evening sky



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Red light friendly

In order to preserve your night vision, you should read our observing guide under red light

06 AUG

Conjunction between the Moon and Jupiter in Leo

- Naked eye
- Binoculars
- Small telescope
- Medium telescope
- Large telescope

Jargon buster

Right Ascension (RA)

Right Ascension is to the sky what longitude is to the surface of the Earth, corresponding to east and west directions. It is measured in hours, minutes and seconds since, as the Earth rotates on its axis, we are able to see different parts of the sky throughout the night.

Magnitude

An object's magnitude tells you how bright it appears from Earth. In astronomy, magnitudes are represented on a numbered scale. The lower the number, the brighter the object will be. So, a magnitude of -1 is brighter than an object with a magnitude of +2.

Greatest elongation

When the inner planets, Mercury and Venus, are at their maximum distance from the Sun. During greatest elongation, the inner planets can be observed as evening stars at greatest eastern elongations and as morning stars during western elongations.

Conjunction

A conjunction is an alignment of objects at the same celestial longitude. The conjunction of the Moon and the planets is determined with reference to the Sun. A planet is in conjunction with the Sun when it and Earth are aligned on opposite sides of the Sun.

Declination (Dec)

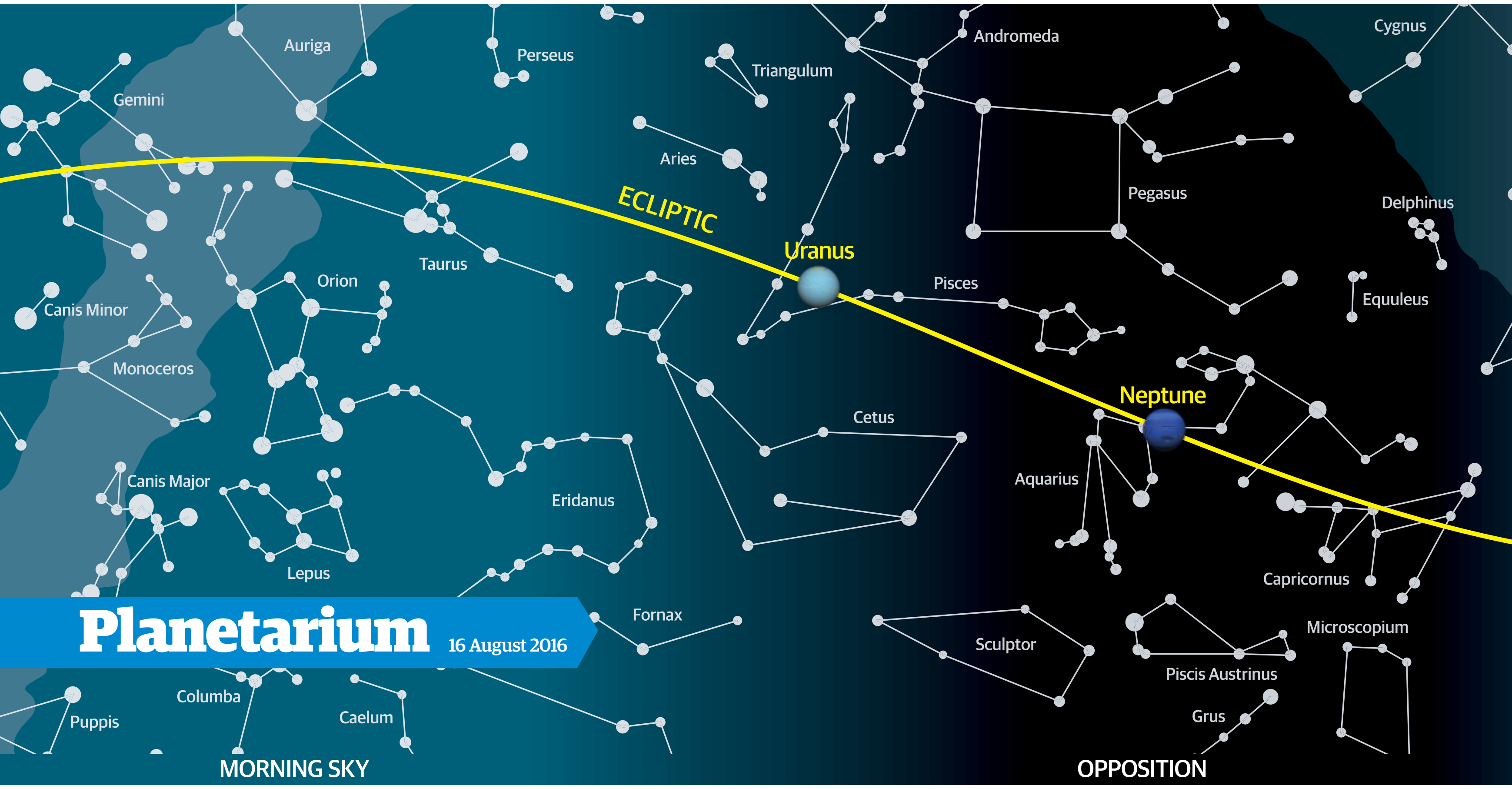
This tells you how high an object will rise in the sky. Like Earth's latitude, Dec measures north and south. It's measured in degrees, arcminutes and arcseconds. There are 60 arcseconds in an arcminute and there are 60 arcminutes in a degree.

Opposition

When a celestial body is in line with the Earth and Sun. During opposition, an object is visible for the whole night, rising at sunset and setting at sunrise. At this point in its orbit, the celestial object is closest to Earth, making it appear bigger and brighter.

Planetarium

16 August 2016



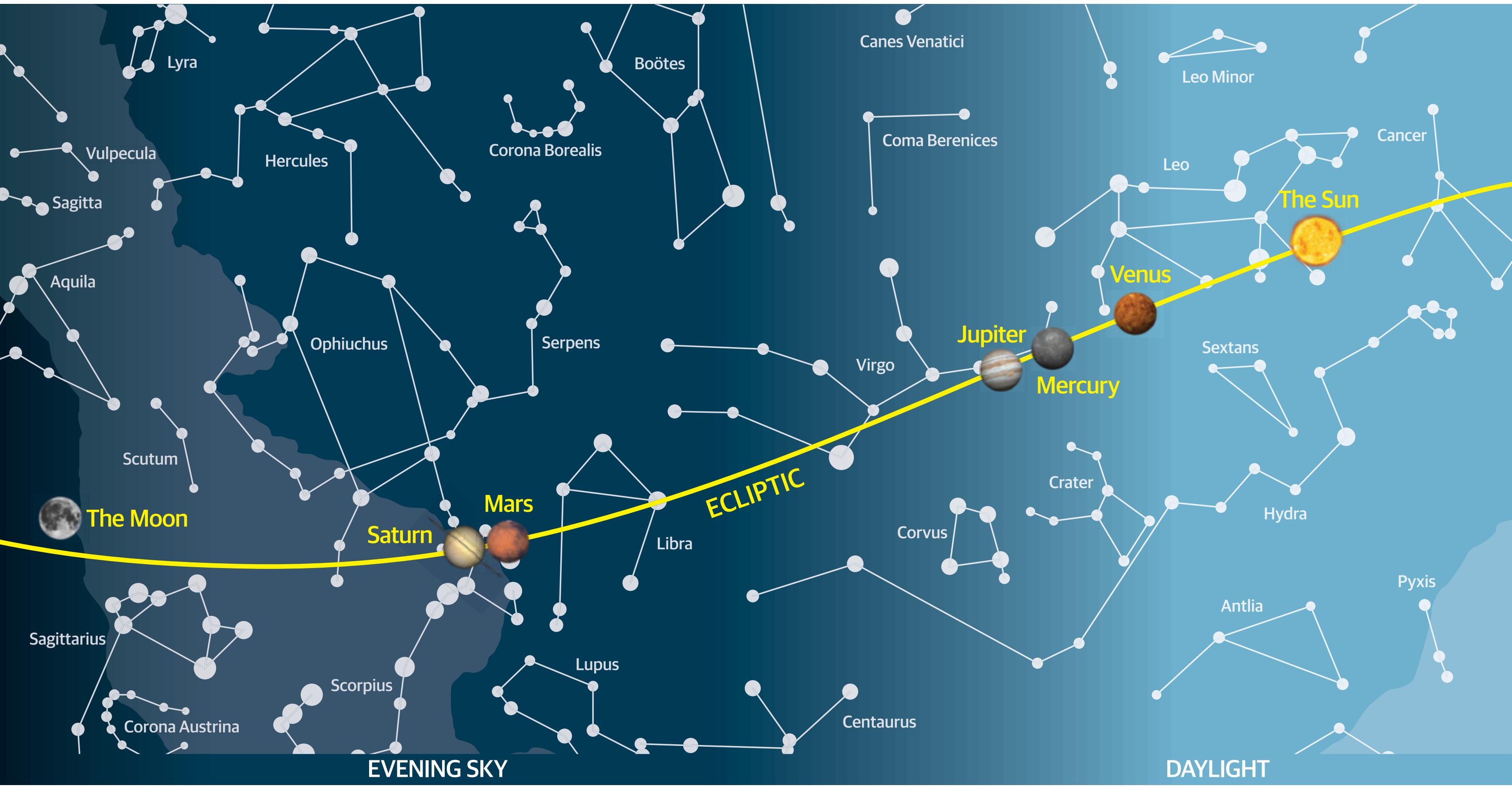
Moon phases

21	JUL		98.6%	◡06:55	◠21:44
22	JUL		94.8%	◡08:07	◠22:15
23	JUL		88.5%	◡09:21	◠22:43
24	JUL		80.1%	◠10:36	◡23:11
25	JUL		69.9%	◡11:51	◠23:39
26	JUL	LQ	58.6%	◡13:07	◠--:--
27	JUL		46.7%	◠00:08	◡14:23
28	JUL		35.0%	◠00:42	◡15:37
29	JUL		24.1%	◠01:20	◡16:48
30	JUL		14.7%	◠02:05	◡17:53
31	JUL		7.4%	◡02:57	◠18:50
1	AUG		2.5%	◠03:57	◡19:38
2	AUG	NM	0.2%	◠05:02	◡20:18
3	AUG		0.5%	◡06:10	◠20:52
4	AUG		3.2%	◠07:18	◡21:21
5	AUG		7.9%	◠08:26	◡21:47
6	AUG		14.4%	◠09:32	◡22:11
7	AUG		22.1%	◠10:37	◡22:34
8	AUG		30.8%	◠11:40	◡22:58
9	AUG		40.2%	◠12:43	◡23:23
10	AUG	FQ	49.9%	◠13:45	◡23:50
11	AUG		59.7%	◠14:45	◡--:--
12	AUG		69.2%	◡00:22	◠15:45
13	AUG		78.2%	◡00:58	◠16:41
14	AUG		86.2%	◡01:42	◠17:34
15	AUG		92.7%	◡02:33	◠18:22
16	AUG		97.4%	◡03:32	◠19:04
17	AUG		98.9%	◡04:38	◠19:42
18	AUG	FM	99.8%	◡05:49	◠20:15

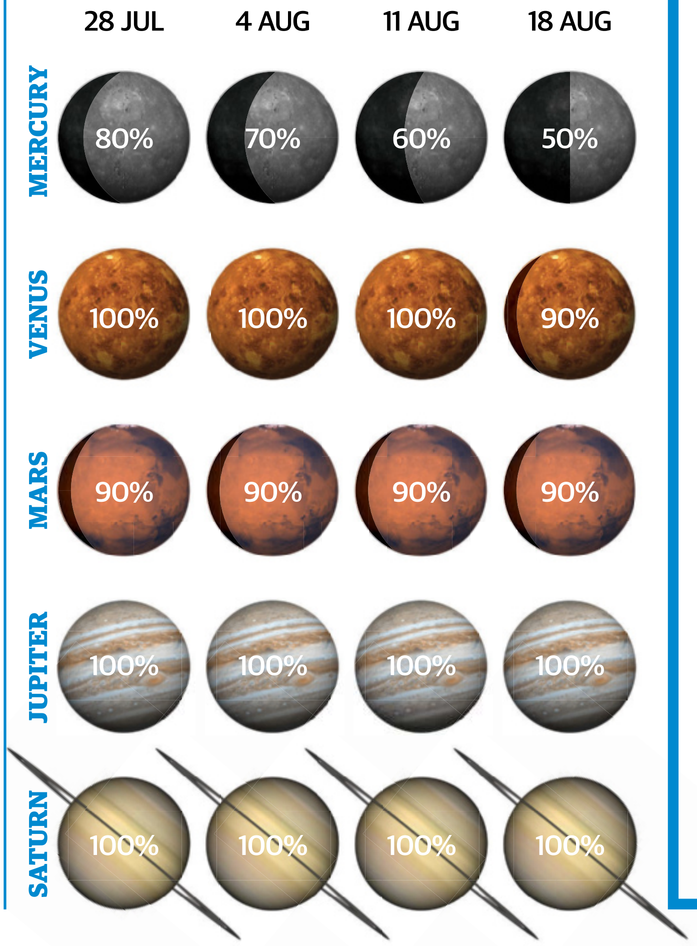
% Illumination
◠ Moonrise time
◡ Moonset time

FM Full Moon
NM New Moon
FQ First quarter
LQ Last quarter

All figures are given for 00h at midnight (local times for London, UK)



Illumination percentage



	28 JUL	4 AUG	11 AUG	18 AUG
MERCURY	80%	70%	60%	50%
VENUS	100%	100%	100%	90%
MARS	90%	90%	90%	90%
JUPITER	100%	100%	100%	100%
SATURN	100%	100%	100%	100%

Planet positions

All rise and set times are given in BST

	Date	RA	Dec	Constellation	Mag	Rise	Set
MERCURY	21 Jul	09h 04m 59s	+18° 26' 11"	Cancer	-0.7	06:23	21:49
	28 Jul	09h 52m 09s	+14° 04' 59"	Leo	-0.3	07:08	21:43
	04 Aug	10h 31m 39s	+09° 27' 50"	Leo	+0.1	07:45	21:30
	11 Aug	11h 04m 10s	+04° 58' 32"	Leo	+0.2	08:14	21:11
	18 Aug	11h 29m 23s	+00° 59' 05"	Leo	+0.4	08:31	20:49
VENUS	21 Jul	08h 53m 36s	+18° 54' 46"	Cancer	-3.9	06:08	21:41
	28 Jul	09h 28m 13s	+16° 27' 41"	Leo	-3.9	06:30	21:33
	04 Aug	10h 01m 52s	+13° 38' 44"	Leo	-3.9	06:53	21:23
	11 Aug	10h 34m 40s	+10° 32' 04"	Leo	-4.0	07:15	21:11
	18 Aug	11h 06m 43s	+07° 11' 51"	Leo	-4.0	07:37	20:58
MARS	21 Jul	15h 30m 31s	-21° 56' 17"	Libra	-1.4	16:28	00:37
	28 Jul	15h 39m 07s	-22° 26' 42"	Libra	-1.3	16:12	00:15
	04 Aug	15h 49m 42s	-23° 00' 10"	Scorpius	-1.2	15:59	23:50
	11 Aug	16h 02m 03s	-23° 34' 59"	Scorpius	-1.1	15:48	23:31
	18 Aug	16h 15m 59s	-24° 09' 17"	Scorpius	-1.0	15:38	23:13
JUPITER	21 Jul	11h 24m 43s	+05° 03' 24"	Leo	-1.8	09:56	22:55
	28 Jul	11h 29m 11s	+04° 33' 57"	Leo	-1.8	09:36	22:29
	04 Aug	11h 33m 52s	+04° 03' 03"	Leo	-1.7	09:15	22:04
	11 Aug	11h 38m 45s	+03° 30' 51"	Virgo	-1.7	08:55	21:38
	18 Aug	11h 43m 49s	+02° 57' 35"	Virgo	-1.7	08:36	21:13
SATURN	21 Jul	16h 34m 25s	-20° 16' 18"	Ophiuchus	+0.9	17:21	01:52
	28 Jul	16h 33m 29s	-20° 15' 49"	Ophiuchus	+0.9	16:52	01:23
	04 Aug	16h 32m 52s	-20° 16' 01"	Ophiuchus	+1.0	16:24	00:55
	11 Aug	16h 32m 34s	-20° 16' 56"	Ophiuchus	+1.0	15:56	00:27
	18 Aug	16h 32m 36s	-20° 18' 34"	Ophiuchus	+1.0	15:29	23:56

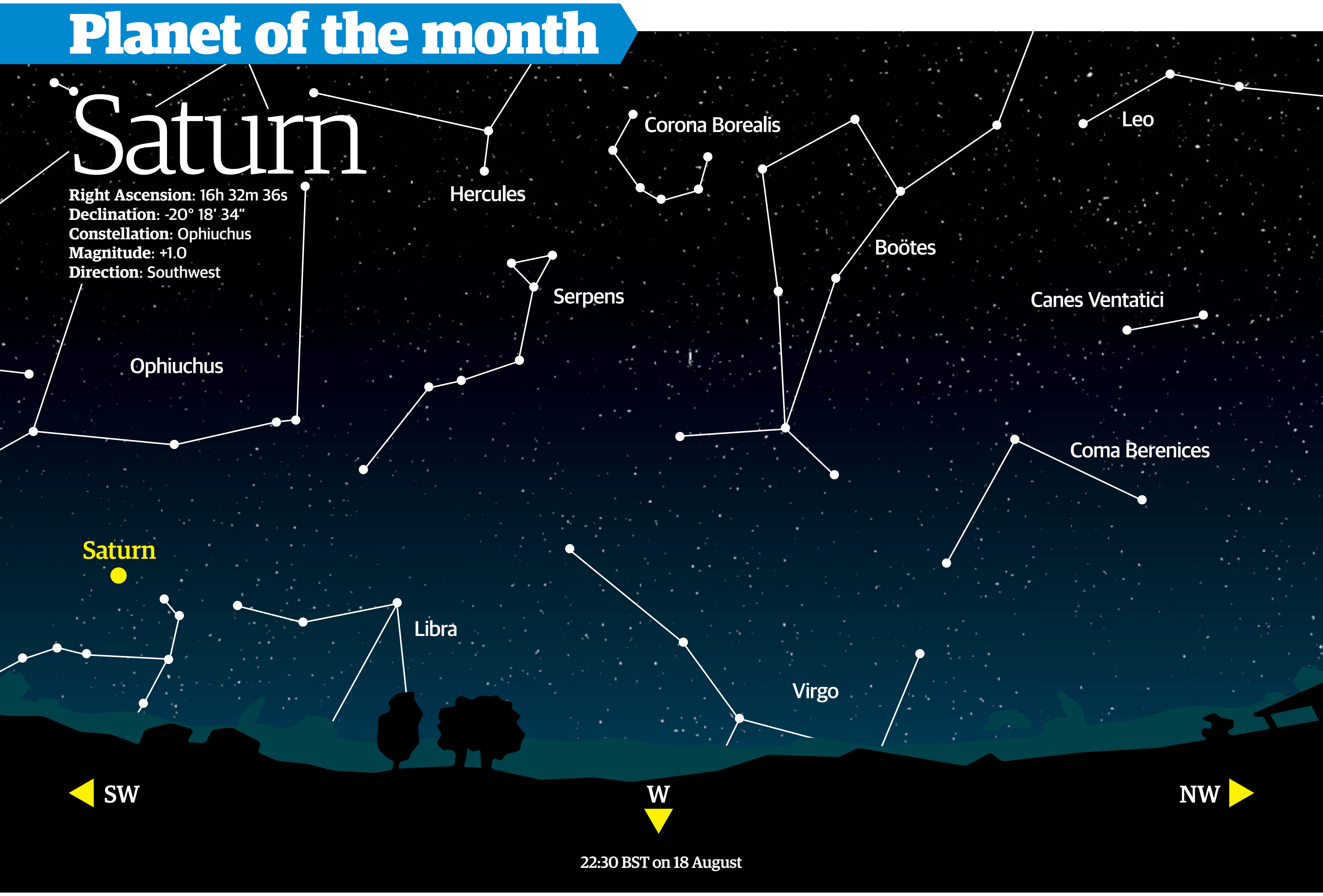
This month's planets

Of the Solar System's five bright naked eye planets, Mars and Saturn present the most easily observable objects in the night sky

Planet of the month

Saturn

Right Ascension: 16h 32m 36s
Declination: -20° 18' 34"
Constellation: Ophiuchus
Magnitude: +1.0
Direction: Southwest



22:30 BST on 18 August

Slim pickings on the planetary front means that the ringed planet Saturn – now more than a month after opposition – is the most readily observable of the Solar System's five brightest planets, so it nominates itself again as planet of the month this issue.

Located pretty far south in the constellation of Ophiuchus, Saturn is six degrees north of the bright red supergiant Antares (also known as Alpha Scorpii or the Rival of Mars), which shines at magnitude +1.0.

On 21 July, just before midnight, the ringed planet can be seen in an astronomically dark sky that is free of any light pollution. At this time, Saturn will be some 15 degrees above the southwestern horizon.

By 18 August at around 10.30pm, Saturn enters an astronomically dark sky at around 11 degrees in altitude; at this time, Mars lies five degrees south of Saturn (at magnitude +0.4) and the pair can be resolved in the same field of view in 7x50 binoculars.

Despite its low altitude, this will be the last opportunity for sky-watchers to view Saturn to reasonably good effect for at least another year.

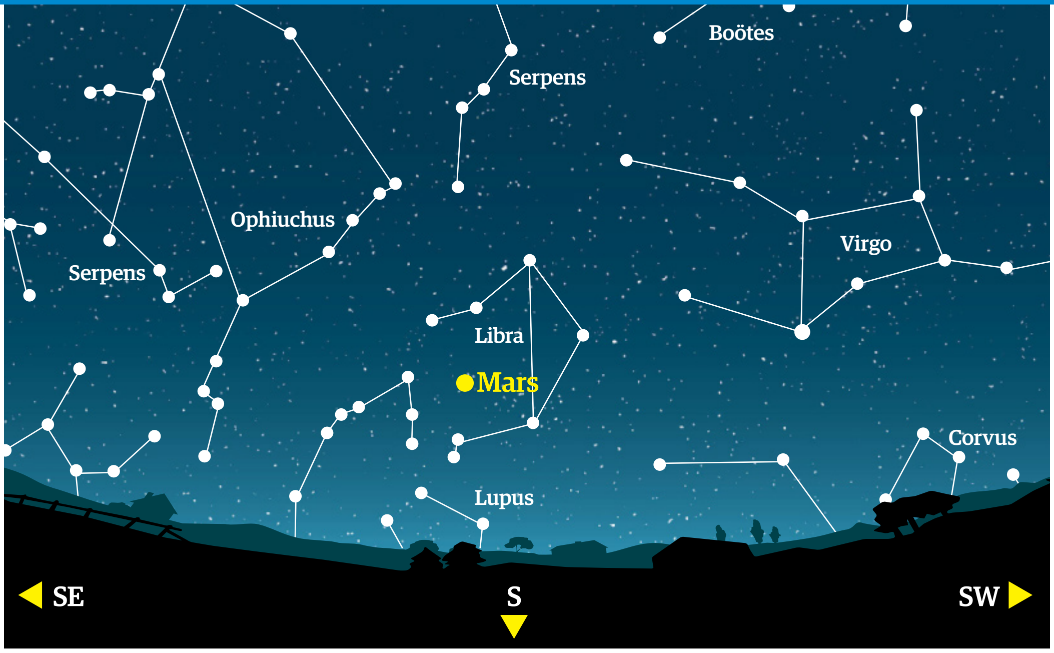
Saturn's rings are wide open for observation (the north face of the rings is turned towards the Earth) and the planet's numerous moons present a beautiful telescopic sight given good sky transparency and favourable observing conditions.

The Cassini Division, which separates the main A and B Ring and is the largest of the gaps between Saturn's rings, can still easily be resolved through quite small telescopes, and the shadow of the globe on the far side of Saturn's rings should be evident.

Owing to the planet's somewhat unfavourable altitude this month, don't expect to see too much in terms of atmospheric detail on the planet's creamy globe. However, it will still be possible to catch a glimpse of the dusky North Equatorial Belt and the North Polar Region.

Mars

21:00 BST on 21 July



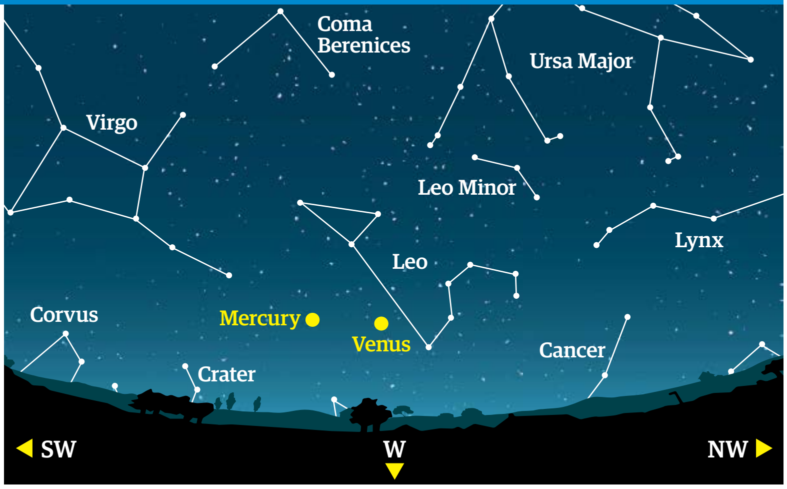
Right Ascension: 15h 30m 31s
Declination: -21° 56' 17"
Constellation: Libra
Magnitude: -1.4
Direction: Southwest

As Mars sinks into the evening twilight it gradually diminishes in brilliance and apparent angular size. Even though it lies 115 degrees east of the Sun, on 21 July Mars is 17 degrees above the southern horizon at sunset (9pm), but has fallen to just five degrees above the southwestern horizon as the twilight darkens to near-astronomical night (around midnight).

Presenting a magnitude -1.4 disc some 14 arcseconds across with a prominent gibbous phase of 89 per cent, some dusky desert detail can still be discerned telescopically, particularly if the skies are clear and favourable. By 18 August, Mars has moved just five degrees south of Saturn (magnitude +0.4); it's best to look for the close planetary pairing at first through binoculars from 10pm onwards (Mars being ten degrees above the southwestern horizon). Through a telescope Mars is now an 86 per cent gibbous disc just 11 arcseconds across.

Mercury and Venus

20:00 BST on 10 August



Right Ascension: 10h 59m 57s
Declination: +05° 35' 43"
Constellation: Leo
Magnitude: -1.8
Direction: West (evening)

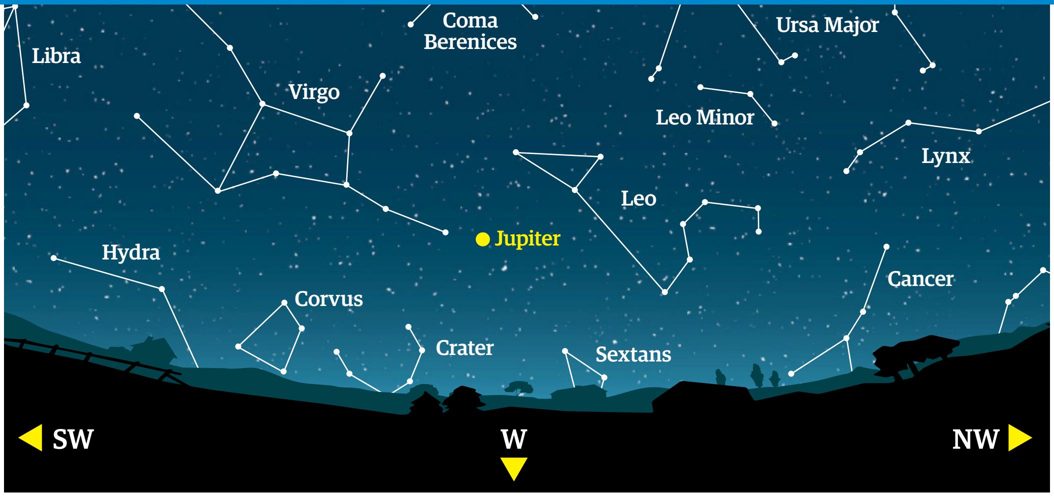
Following Mercury's superior conjunction on 7 July, the planet moves east of the Sun, but note that it is by no means easily visible during this period to most amateur astronomers due to its proximity to the glare of the Sun and its low altitude above the sunset horizon. Most astronomers will wait further into Mercury's eastern elongation, the most ideal opportunity to view it presenting itself on 16 August when Mercury reaches greatest eastern elongation from the Sun (27 degrees); at this time, Mercury is just five degrees above the western horizon at sunset (8.30pm BST). Still, most observers are liable to give this elongation a wide berth owing to the difficulty of observation.

Right Ascension: 10h 30m 02s
Declination: +10° 59' 39"
Constellation: Leo
Magnitude: -4.0
Direction: West (evening)

Venus is an early evening object but like Mercury, it is virtually unobservable between 21 July and 18 August due to its proximity to the Sun.

Jupiter

20:00 BST on 5 August



Right Ascension: 11h 34m 33s
Declination: +03° 58' 31"
Constellation: Leo
Magnitude: -1.7
Direction: West (evening)

Jupiter is nominally an evening object but like Mercury and Venus, it is located so close to the Sun during this period that it is virtually unobservable. However, it may just be glimpsed low above the western horizon through binoculars in the bright twilight a short while after sunset. Under no circumstances attempt to view Mercury, Venus or Jupiter before sunset while the Sun is directly visible, either through binoculars or a telescope. One inadvertent glimpse of magnified, unfiltered sunlight can easily cause eye damage, perhaps permanent retinal scarring or even partial blindness.

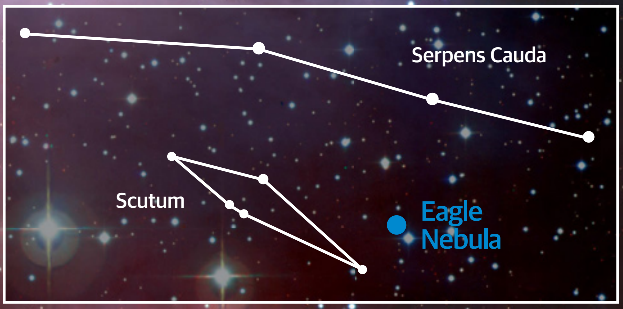
OBSERVE SUMMER NEBULAE TONIGHT

The nights may be short, but they're perfect for finding some of the most fascinating objects in the sky

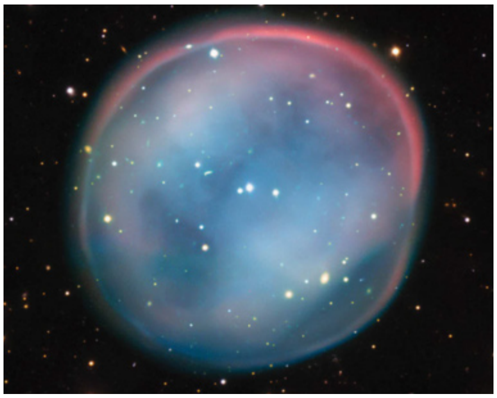
Written by Stuart Atkinson

Eagle Nebula (M16)
Constellation: Serpens
Magnitude: +6
Minimum equipment: Naked eye (under very dark sky)
Type of nebula: Emission nebula

M16 is one of greedy Sagittarius' hoard of deep sky wonders, but you'll only see it as a vague smudge on the Milky Way from a dark sky site, and binoculars are needed to bring it into clear view. Even then, you'll just see a small area of misty grey. A small telescope will reveal hints of dark mottling in its centre – the famous 'Pillars of Creation' photographed so beautifully and famously by the Hubble Space Telescope.

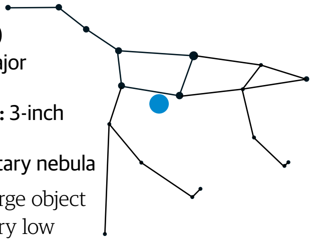


Observe summer nebulae tonight

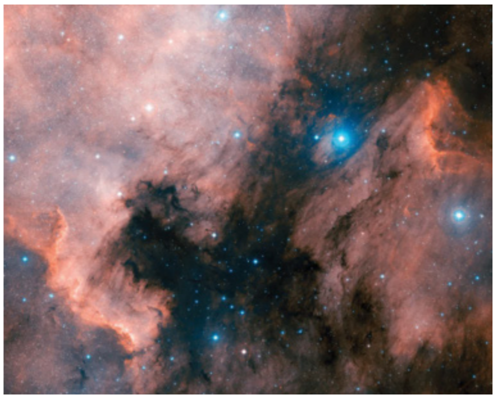


Owl Nebula (M97)

Constellation: Ursa Major
Magnitude: +9.8
Minimum equipment: 3-inch telescope
Type of nebula: Planetary nebula

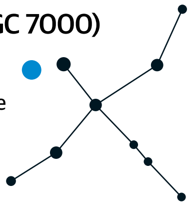


The Owl Nebula is a large object visually but it has a very low surface brightness. Although it can just be glimpsed through small telescopes as an out of focus star in your eyepiece, this planetary nebula - interestingly, one of only four catalogued by Messier - is best viewed through medium or large telescopes of 10-inches or larger in order to do it justice. This will reveal a round misty cloud with a pair of darker regions inside it - the eyes of a cosmic owl, staring back at us from 2,000 light years away.

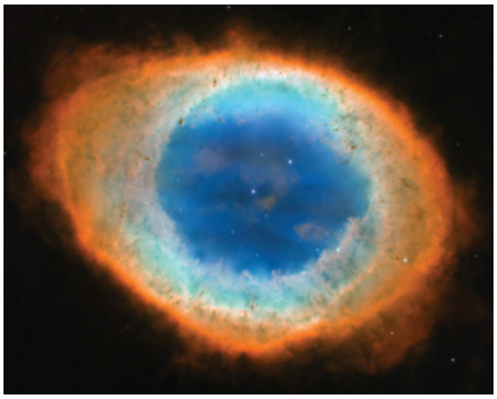


North America Nebula (NGC 7000)

Constellation: Cygnus
Magnitude: +6
Minimum equipment: Naked eye (under a dark sky)
Type of nebula: Reflection nebula

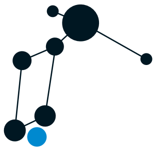


The North America Nebula gets its name, as you can probably guess, from the fact that it looks like the continent of North America - in long-exposure photographs at least. To naked eye observers it is a slightly bright patch of sky close to the star Deneb, best seen out of the corner of your eye - or by using 'averted vision', as astronomers call it. Through binoculars, NGC 7000 has a slightly more obvious greyness. However, it will take a telescope to reveal its North-America-shaped outline.

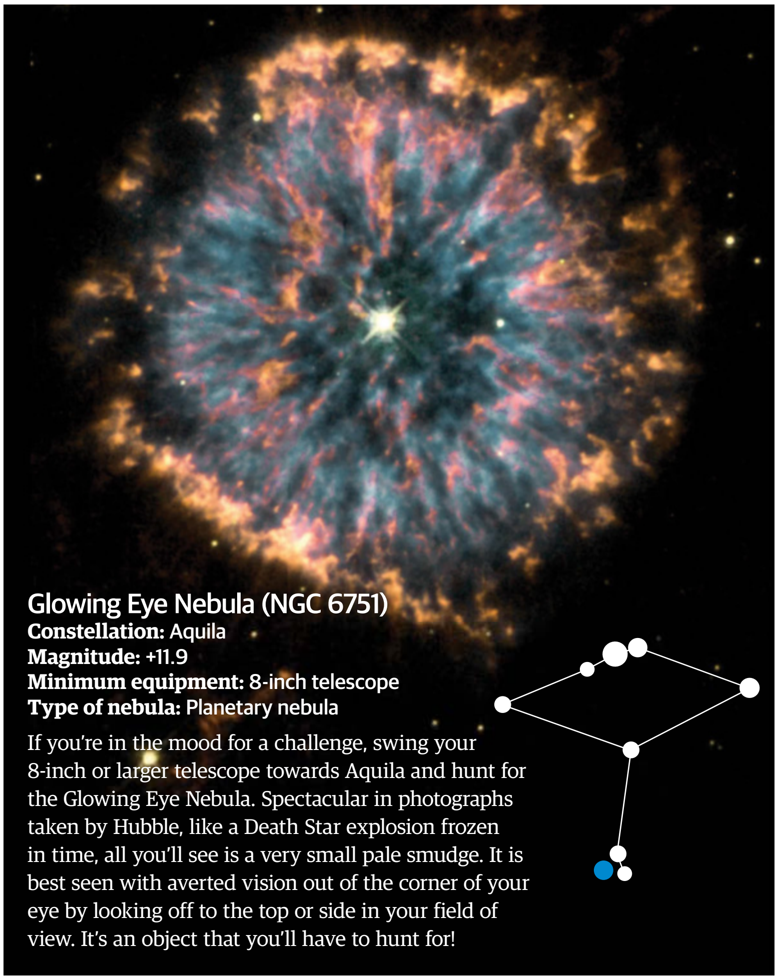


Ring Nebula (M57)

Constellation: Lyra
Magnitude: +8
Minimum equipment: 10x50 binoculars
Type of nebula: Planetary nebula



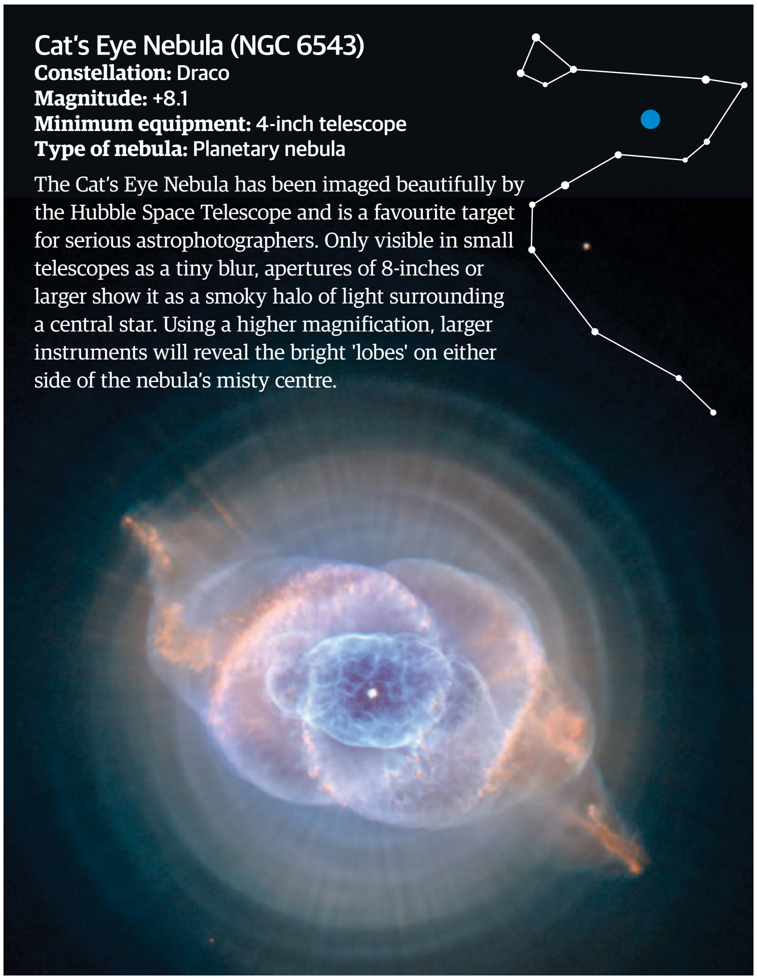
Lying close to the brilliant star Vega, which blazes overhead through summer nights, M57 is probably the most famous and most photographed planetary nebula in the whole sky. But it is very, very small, and through binoculars, even under a very dark sky, all you'll see is an out-of-focus star that is hard to pick out from the real stars around it. It takes a small telescope to resolve the nebula as a tiny smoke ring of pale grey. Larger instruments bring out more detail - subtle knots here and there - and also reveal the star in its centre.



Glowing Eye Nebula (NGC 6751)

Constellation: Aquila
Magnitude: +11.9
Minimum equipment: 8-inch telescope
Type of nebula: Planetary nebula

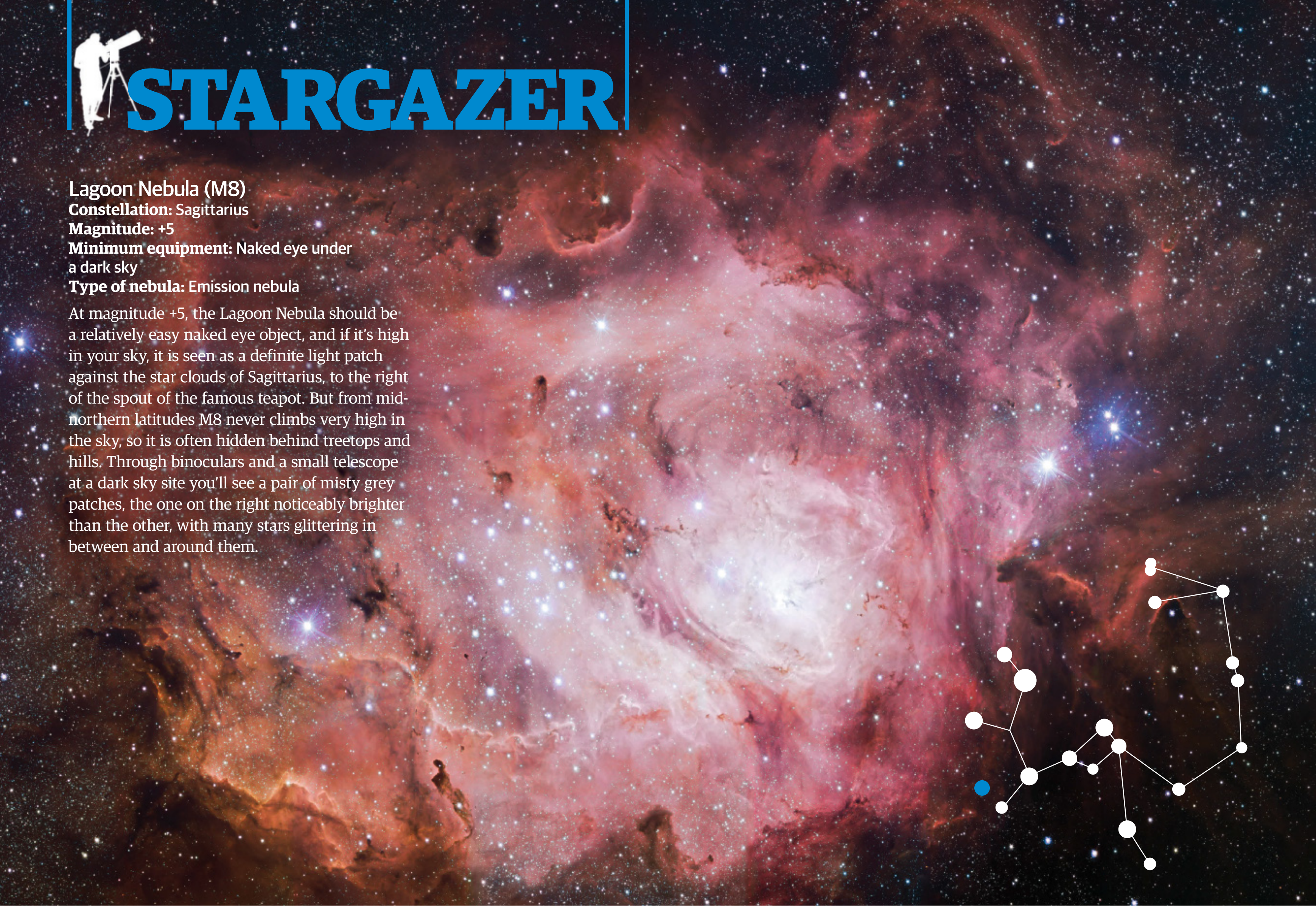
If you're in the mood for a challenge, swing your 8-inch or larger telescope towards Aquila and hunt for the Glowing Eye Nebula. Spectacular in photographs taken by Hubble, like a Death Star explosion frozen in time, all you'll see is a very small pale smudge. It is best seen with averted vision out of the corner of your eye by looking off to the top or side in your field of view. It's an object that you'll have to hunt for!



Cat's Eye Nebula (NGC 6543)

Constellation: Draco
Magnitude: +8.1
Minimum equipment: 4-inch telescope
Type of nebula: Planetary nebula

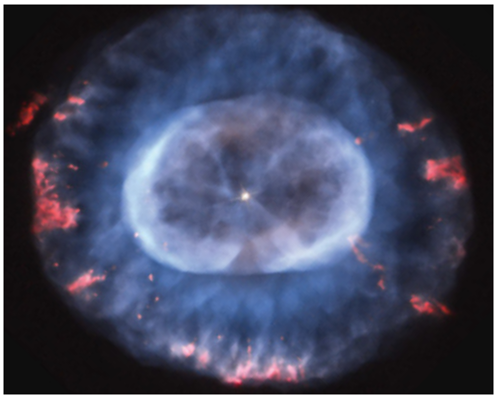
The Cat's Eye Nebula has been imaged beautifully by the Hubble Space Telescope and is a favourite target for serious astrophotographers. Only visible in small telescopes as a tiny blur, apertures of 8-inches or larger show it as a smoky halo of light surrounding a central star. Using a higher magnification, larger instruments will reveal the bright 'lobes' on either side of the nebula's misty centre.



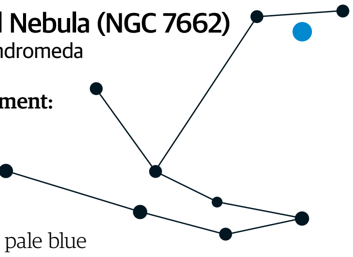
Lagoon Nebula (M8)

Constellation: Sagittarius
Magnitude: +5
Minimum equipment: Naked eye under a dark sky
Type of nebula: Emission nebula

At magnitude +5, the Lagoon Nebula should be a relatively easy naked eye object, and if it's high in your sky, it is seen as a definite light patch against the star clouds of Sagittarius, to the right of the spout of the famous teapot. But from mid-northern latitudes M8 never climbs very high in the sky, so it is often hidden behind treetops and hills. Through binoculars and a small telescope at a dark sky site you'll see a pair of misty grey patches, the one on the right noticeably brighter than the other, with many stars glittering in between and around them.

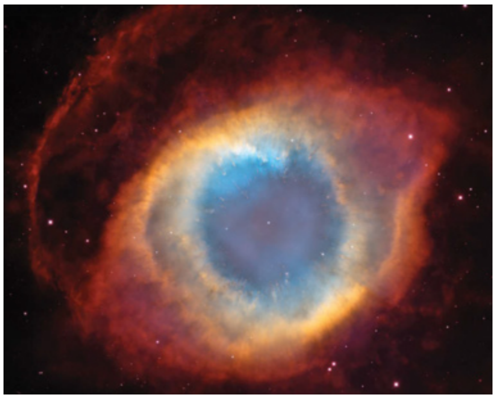


Blue Snowball Nebula (NGC 7662)

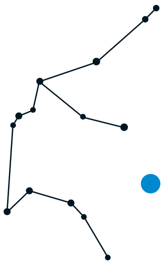


Constellation: Andromeda
Magnitude: +9.2
Minimum equipment: 4-inch telescope
Type of nebula: Planetary nebula

Although it looks little more than a pale blue star in small telescopes, the Blue Snowball Nebula genuinely can look like a tiny blue puffball in larger instruments, although that seems to be a very personal thing; many observers say they can see no colour in the nebula and that it looks like a pale grey ball in their telescopes. An 8-inch telescope is needed to sharpen up the nebula's edges and make it stand out from the background sky.

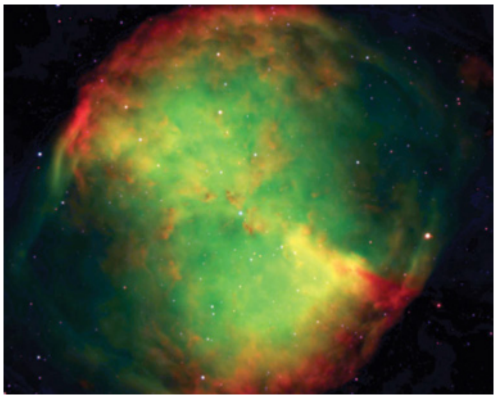


Helix Nebula (NGC 7293)

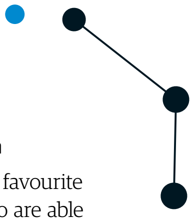


Constellation: Aquarius
Magnitude: +7.6
Minimum equipment: 10x50 binoculars under very dark sky
Type of nebula: Planetary nebula

While this famous planetary nebula appears half the size of the full Moon, seeing it is a real challenge for mid-northern latitude observers. Since it traces out a shallow arc across the southeastern sky, you won't be able to see the Helix Nebula unless you have a low horizon that is free from trees, buildings and hills. The Helix is the closest planetary nebula to Earth, but not close enough for binoculars to show it as anything more than a pale, round smudge. In a small telescope it looks much more like a smoke ring.



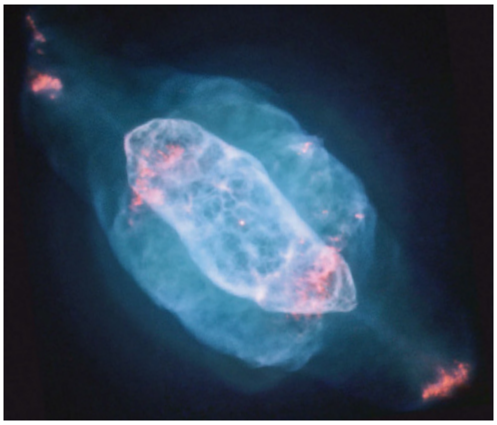
Dumbbell Nebula (M27)



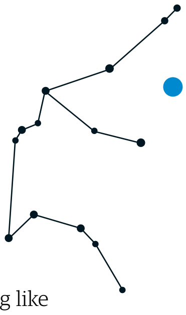
Constellation: Vulpecula
Magnitude: +7.5
Minimum equipment: 10x50 binoculars
Type of nebula: Planetary nebula

The Dumbbell Nebula is another favourite target for astrophotographers who are able to take long-exposure photographs through large telescopes, but it is a major visual challenge requiring a very dark, clear sky. Binoculars show it as just a tiny blurry spot, and a small telescope reveals only an oval-shaped grey smudge. Larger telescopes are needed to resolve its twin fan-shaped lobes of gas and reveal how it got its name. They also show tantalising hints of pale green in the nebula itself. This is most definitely a summer challenge!

Observe summer nebulae tonight

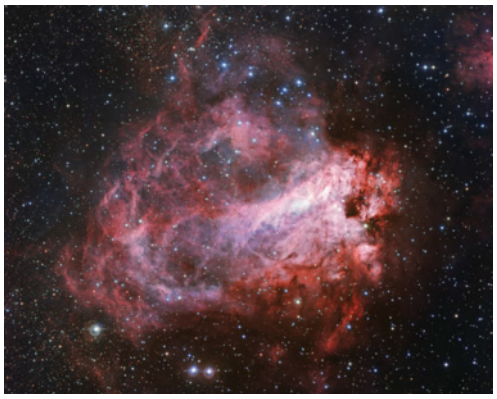


Saturn Nebula (NGC 7009)

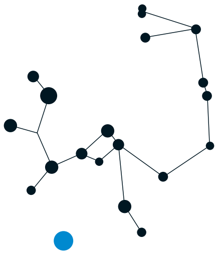


Constellation: Aquarius
Magnitude: +8
Minimum equipment: 3-inch telescope
Type of nebula: Planetary nebula

Without even looking at this nebula you can probably guess what it looks like through a large telescope! Through a small telescope the nebula looks nothing like the most famous ringed planet, instead it looks more like a tiny, slightly green-hued, out-of-focus star. Some observers say it reminds them of Uranus. Through larger telescopes though, with greater magnification, the nebula begins to resemble Saturn, with bright 'arms' on either side reminiscent of Saturn's rings. It's interesting to compare this nebula to the more circular Helix Nebula.

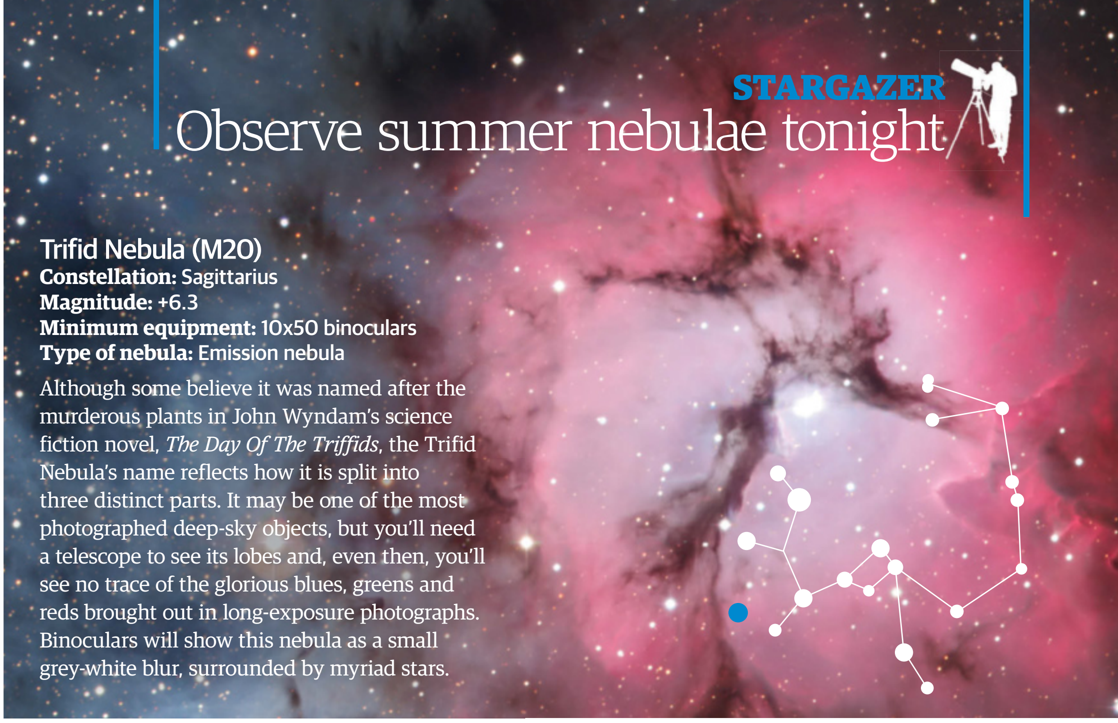


Omega Nebula (M17)



Constellation: Sagittarius
Magnitude: +6
Minimum equipment: Naked eye (under very dark sky)
Type of nebula: Emission nebula

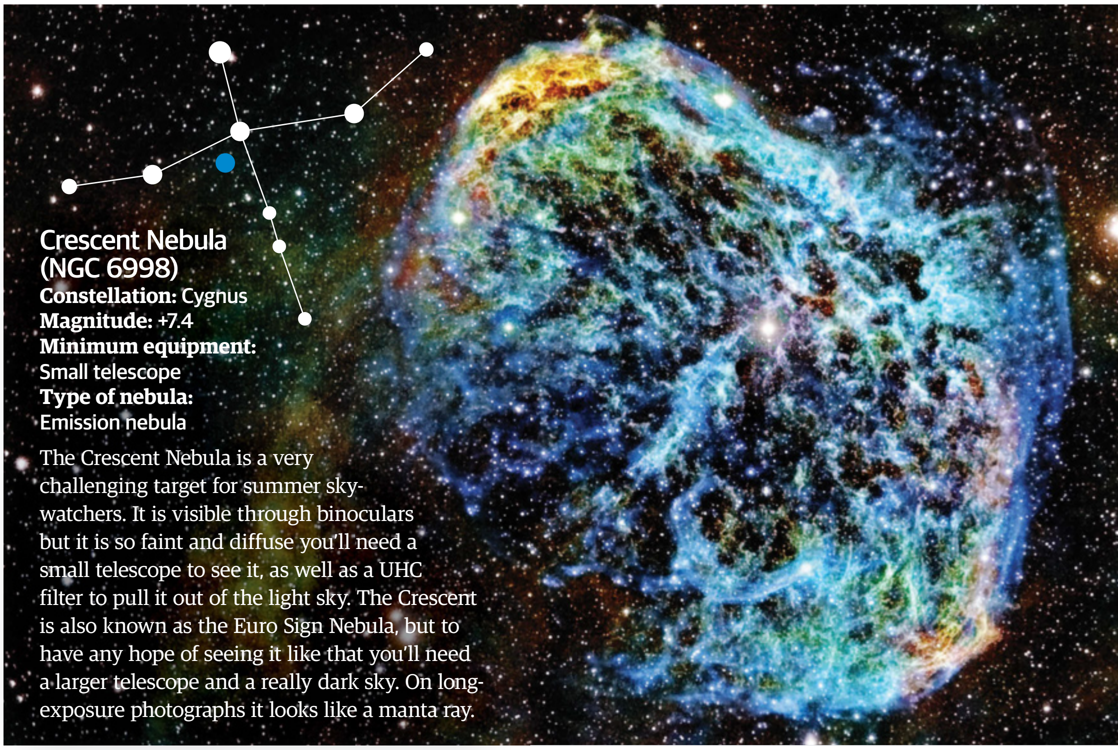
The Omega Nebula is one of several summer nebulae lying among the frothy star-clouds of Sagittarius. Although its +6 magnitude makes it a naked-eye object, all you'll see with your eye, even under a dark sky, is a tiny smudge. Binoculars will bring it into sharper focus, but even then all you'll see is a misty patch. A small telescope is needed to show you why it is named after the last letter of the Greek alphabet and why some think it looks like a swan or a horseshoe.



Trifid Nebula (M20)

Constellation: Sagittarius
Magnitude: +6.3
Minimum equipment: 10x50 binoculars
Type of nebula: Emission nebula

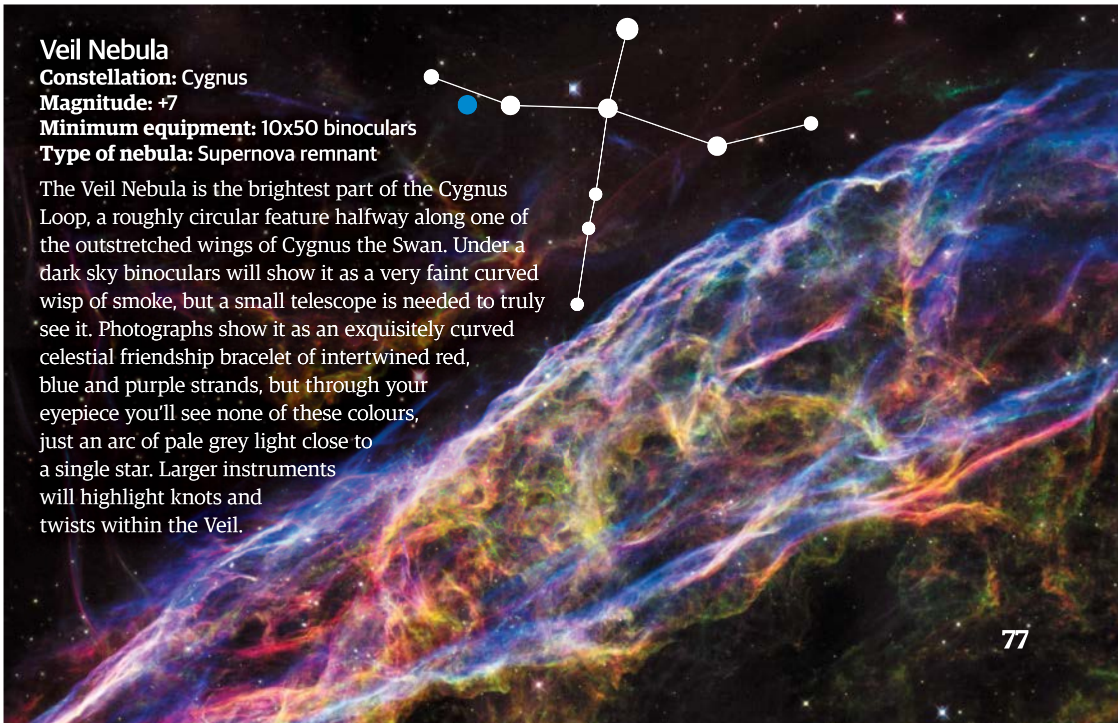
Although some believe it was named after the murderous plants in John Wyndam's science fiction novel, *The Day Of The Triffids*, the Trifid Nebula's name reflects how it is split into three distinct parts. It may be one of the most photographed deep-sky objects, but you'll need a telescope to see its lobes and, even then, you'll see no trace of the glorious blues, greens and reds brought out in long-exposure photographs. Binoculars will show this nebula as a small grey-white blur, surrounded by myriad stars.



Crescent Nebula (NGC 6998)

Constellation: Cygnus
Magnitude: +7.4
Minimum equipment: Small telescope
Type of nebula: Emission nebula

The Crescent Nebula is a very challenging target for summer sky-watchers. It is visible through binoculars but it is so faint and diffuse you'll need a small telescope to see it, as well as a UHC filter to pull it out of the light sky. The Crescent is also known as the Euro Sign Nebula, but to have any hope of seeing it like that you'll need a larger telescope and a really dark sky. On long-exposure photographs it looks like a manta ray.



Veil Nebula

Constellation: Cygnus
Magnitude: +7
Minimum equipment: 10x50 binoculars
Type of nebula: Supernova remnant

The Veil Nebula is the brightest part of the Cygnus Loop, a roughly circular feature halfway along one of the outstretched wings of Cygnus the Swan. Under a dark sky binoculars will show it as a very faint curved wisp of smoke, but a small telescope is needed to truly see it. Photographs show it as an exquisitely curved celestial friendship bracelet of intertwined red, blue and purple strands, but through your eyepiece you'll see none of these colours, just an arc of pale grey light close to a single star. Larger instruments will highlight knots and twists within the Veil.

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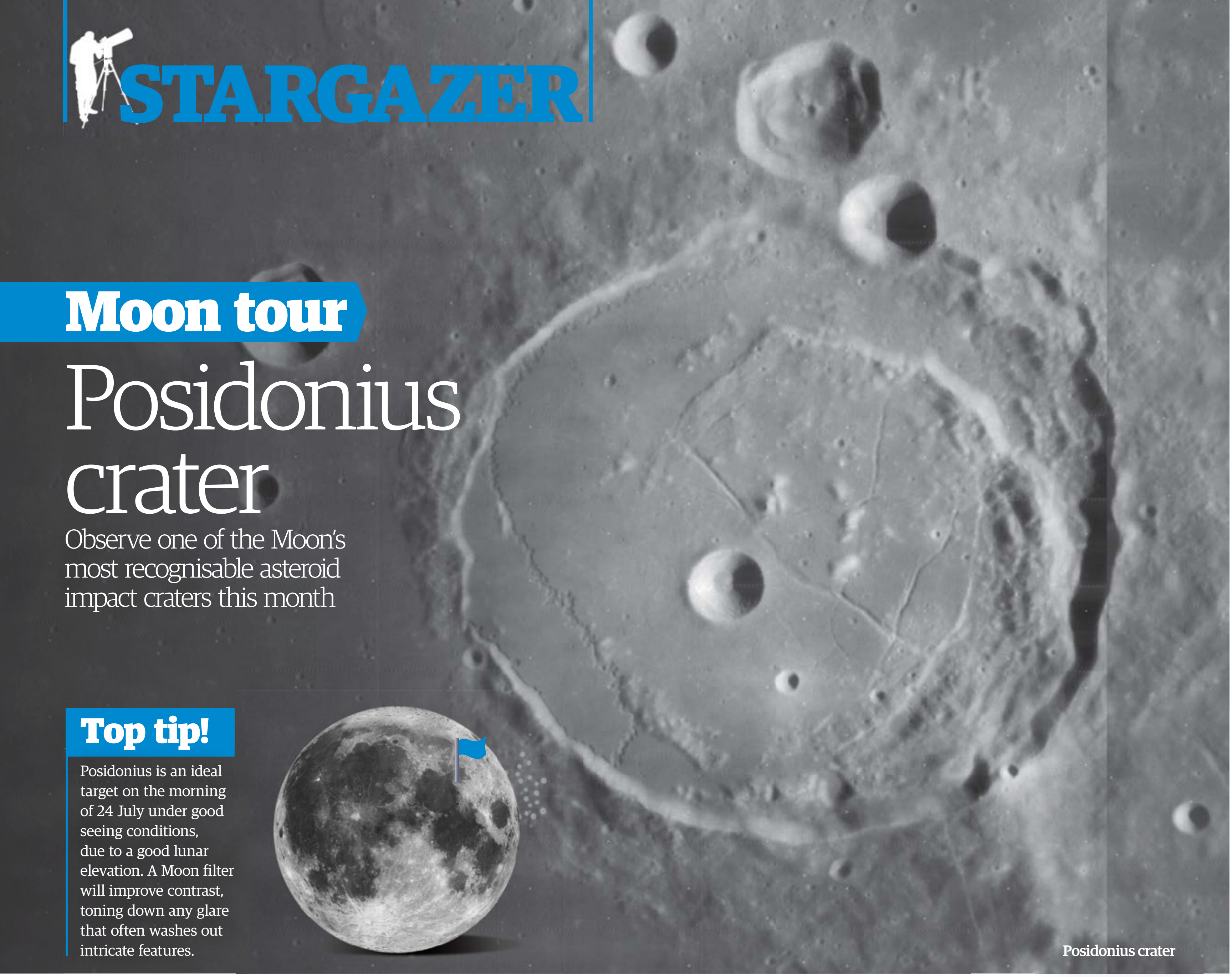


Moon tour

Posidonius crater

Observe one of the Moon's most recognisable asteroid impact craters this month

Top tip!

Posidonius is an ideal target on the morning of 24 July under good seeing conditions, due to a good lunar elevation. A Moon filter will improve contrast, toning down any glare that often washes out intricate features.

Posidonius crater

One of the Moon's most sublime and recognisable craters - Posidonius - can be viewed to good advantage, as it is illuminated by a local evening lunar Sun on the morning of 24 July. The Moon is situated at a handsome altitude above the southeastern horizon and will be 26 degrees high at 2am BST.

Two weeks later, the Moon lies low above the western horizon as the dusk skies are darkening, but vigilant telescopic observers may still be able to make out Posidonius near the lunar sunrise terminator, despite the Moon's low twilight altitude.

Measuring 95 kilometres (59 miles) across, Posidonius is a prominent crater that lies at the northeastern border of the large near-circular Mare Serenitatis (Sea of Serenity) and at the entrance to Lacus Somniorum (Lake of Dreams), an irregular, lava-filled plain that forms a short arc parallel to the northeastern shoreline of Mare Serenitatis. When illuminated, the Posidonius crater is easily identified through small optical instruments and even steadily-mounted 7x50 binoculars.

However, the complex nature of Posidonius is only revealed under good seeing conditions and through telescopes larger than 80mm at a magnification of higher than 50x. Most noticeable is the fact that the southern rim of Posidonius is joined with the disintegrated crater, Chacornac. While both Posidonius and Chacornac are asteroid impact craters, the more eroded topography of Chacornac suggests that it predates the formation of Posidonius by several hundred million years.

Both craters are thought to have formed after the Serenitatis basin, as their outlines appear impressed over the basin's outline and both are filled with Serenitatis lava flows. Chacornac is likely to have been formed some time before the nearby Imbrium basin was formed, while Posidonius is thought to have been formed shortly after the Imbrium basin impact around 3.8 billion years ago, one of the final episodes of the Late Heavy Bombardment period, when the inner Solar System was a veritable cosmic shooting gallery of asteroids, comets and other debris from the formation of the planets.

Posidonius is one of the Moon's more unusual large craters, possessing a low but complete and clear-cut rim (north and northeastern parts of which are overlain by numerous smaller craters - Posidonius J, B and D). No traces of the initial external impact remain visible because of later lava flooding in Mare Serenitatis and Lacus Somniorum.

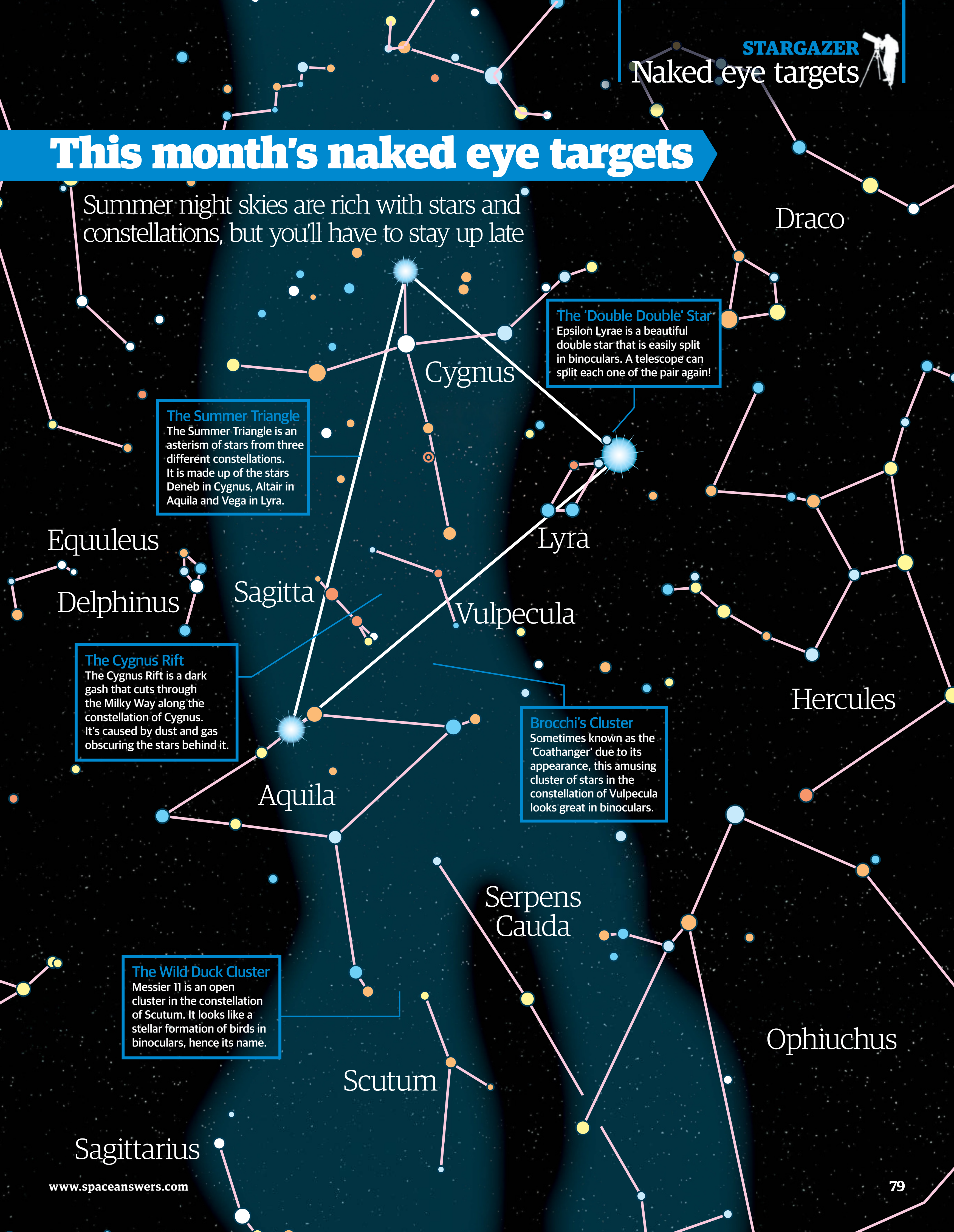
The interior of Posidonius presents a variety of complexity, though visibility is dependent on seeing conditions and the instrument/magnification used. A prominent, clear-cut, bowl-shaped crater, Posidonius A, sits slightly west of the floor centre at 12 kilometres (74 miles) wide - this is easily seen through small optical instruments.

East of Posidonius A there are a number of small valleys; the linear rilles of Rimae Posidonius, the most prominent of which cuts 50 kilometres (31 miles) across the centre of the floor, and it is cut across itself at a right angle by a smaller rille. Another longer rille makes its way along the floor near the inner western wall. The best views of the Rimae Posidonius are to be obtained through a 150mm telescope at a high magnification. A prominent curving ridge crosses the eastern part of Posidonius' floor - a huge block of crust appears to have slipped away from the main eastern wall.

Chacornac appears much more irregular than Posidonius, with a crustal imprint that's obviously less fresh. Like Posidonius, it has an eastern central crater named Chacornac A (at five kilometres, or 3.1 miles, wide) and several rilles (Rimae Chacornac) that run northwest-southeast across its floor - easily visible through a 150mm telescope at high power and under a low illumination. Together, Posidonius and Chacornac present a highly interesting lunar sight when illuminated.

This month's naked eye targets

Summer night skies are rich with stars and constellations, but you'll have to stay up late



The 'Double Double' Star
Epsilon Lyrae is a beautiful double star that is easily split in binoculars. A telescope can split each one of the pair again!

The Summer Triangle
The Summer Triangle is an asterism of stars from three different constellations. It is made up of the stars Deneb in Cygnus, Altair in Aquila and Vega in Lyra.

The Cygnus Rift
The Cygnus Rift is a dark gash that cuts through the Milky Way along the constellation of Cygnus. It's caused by dust and gas obscuring the stars behind it.

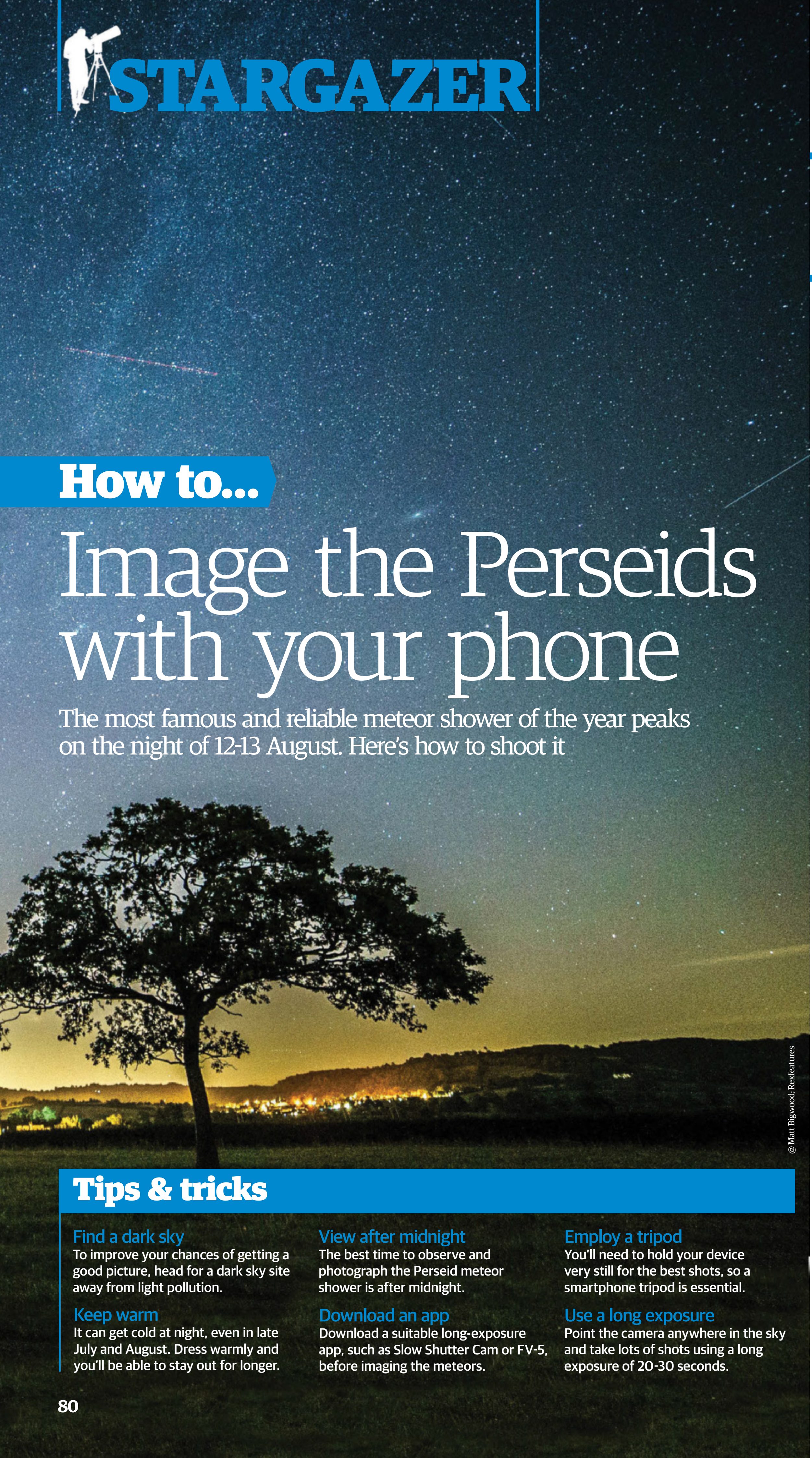
Brocchi's Cluster
Sometimes known as the 'Coathanger' due to its appearance, this amusing cluster of stars in the constellation of Vulpecula looks great in binoculars.

The Wild Duck Cluster
Messier 11 is an open cluster in the constellation of Scutum. It looks like a stellar formation of birds in binoculars, hence its name.

How to...

Image the Perseids with your phone

The most famous and reliable meteor shower of the year peaks on the night of 12-13 August. Here's how to shoot it



@ Matt Bigwood; Rexfeatures

You'll need:

- ✔ Smartphone
- ✔ Suitable app
- ✔ Tripod for phones

Meteor showers are associated with comets. When the Earth passes through the dust and debris left behind by the comet as it orbits the Sun, these particles fall through the atmosphere at high speed and burn up due to friction as they rub against the air molecules. This is what we see as meteors, or shooting stars, as they flash across the sky in streaks of light.

Because we know roughly when we pass through the dust and debris left behind by various comets, we can predict when we are likely to see meteors. It can take several days or weeks to pass through this dust, but when we go through the thickest part, we experience a peak of meteor activity over one or two nights.

This month we pass through the dust left behind by comet Swift-Tuttle, and we travel through the most concentrated part of this on the night of 12-13 August each year. Because of the way we pass through these meteor streams, the meteors themselves appear to radiate from a single point in the sky, known as the radiant. The radiant for the Perseids is, not surprisingly, located in the constellation of Perseus. This means that the meteors seem to streak across the sky from this point. They can travel in any direction and vary in brightness depending on size, but most of them are only the size of a grain of sand. The Perseids are, on the whole, fast-moving and bright.

The term meteor 'shower' can be a little misleading though. Don't expect it to be raining meteors! This can occur, but very rarely, in which case the shower is called a storm. However, at the peak of the Perseids you can expect to see several streaks, known as events, per hour. You can record the meteors with a smartphone, but to do this you'll need to download an app to extend the exposure time. For iPhones you can use 'Slow Shutter Cam' and for Androids you can download 'FV-5'. These apps allow you to set the exposure time and ISO manually. Up to 30 seconds exposure is ideal for meteors. Point the smartphone at any part of the sky once it is attached to your tripod and start taking pictures. You never know, you might be lucky and snap a bright meteor.

Tips & tricks

Find a dark sky

To improve your chances of getting a good picture, head for a dark sky site away from light pollution.

Keep warm

It can get cold at night, even in late July and August. Dress warmly and you'll be able to stay out for longer.

View after midnight

The best time to observe and photograph the Perseid meteor shower is after midnight.

Download an app

Download a suitable long-exposure app, such as Slow Shutter Cam or FV-5, before imaging the meteors.

Employ a tripod

You'll need to hold your device very still for the best shots, so a smartphone tripod is essential.

Use a long exposure

Point the camera anywhere in the sky and take lots of shots using a long exposure of 20-30 seconds.

Capturing the Perseids

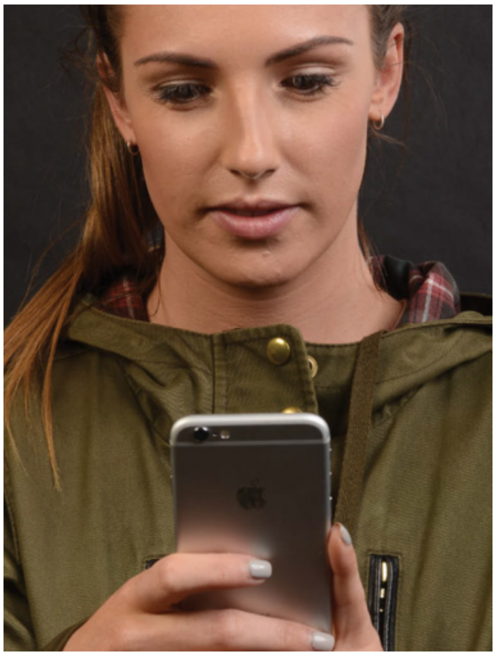
Successfully image one of the most famous meteor showers

Imaging meteors involves a little knowledge and a lot of luck. You can improve your chances of success by following the steps below. Be persistent: you're likely to see a few meteors if you stay out for at least 20 minutes. The longer you're outside, the more your chances increase. Being comfortable and warm will make the experience more enjoyable. Again, if you take more images, you are more likely to capture a meteor. Try not to be disappointed if you don't catch any though, as there's always next year!

Send your photos to
photos@spaceanswers.com

1 Wear plenty of layers

It can get very cold at night, even during the summer months, so dress appropriately. A garden chair is good for comfort, too.



2 Get to know your app

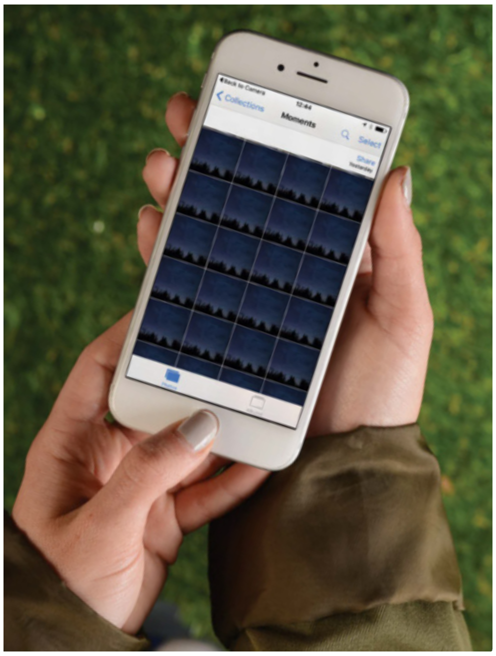
Try out your long-exposure app before the meteor shower, to increase your chances of getting a good image of the Perseids on the night.

3 Set up your tripod

Even a small tabletop tripod - compatible with your smartphone - will help to keep your device steady and your images sharp.

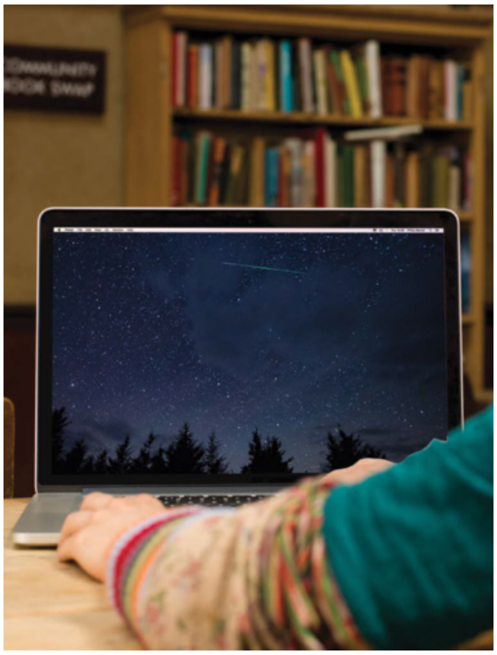
4 Aim your camera

Point your camera almost anywhere in the sky. You never know when the next meteor will whizz past or in what direction it will come from.



5 Take lots of shots

Take as many pictures as your smartphone's memory can handle. This will increase your chances of catching a meteor.



6 Process your images

You can download your pictures the next day and start to sort and process them to see if you've bagged a few meteors.

Deep sky challenge

Nebulae and stars of Cygnus and Lyra

The skies are alive with star-forming regions and stellar gatherings waiting to be observed

One of the most interesting regions of the sky at this time of year is the area around the constellations of Cygnus and Lyra. Cygnus lies in the Milky Way and is packed full of star clusters and nebulae to keep anyone with a telescope busy for many nights. We have two of the brightest planetary nebulae in all of the night skies, along with a glorious double star and a faint but extensive region of dust and gas. Not only that, we can see one of the most beautiful supernova remnants in the heavens too!

This whole region is teeming with deep sky objects to turn your telescope to. You can just cruise through the Milky Way here and be amazed at the densely packed stars and pick up many fully-fledged star clusters and nebulae on your tour. A star chart is useful to have with you to help identify the objects that you come across. Alternatively, have a go at the objects mentioned here. There's something for every size of telescope and experience. Summer starry skies are certainly worth staying up late for.

1 The Ring Nebula (M57)

M57, known as the Ring Nebula, is the brightest and best of the 'planetary nebula'. It has nothing to do with planets, however, but is the remnant of a dying star.

2 North America Nebula (NGC 7000)

The North America Nebula due to its shape, this extended object is best viewed with a deep sky H-Alpha filter and a low magnification. The central part of the North America Nebula is named the Cygnus Wall.

3 The Veil Nebula

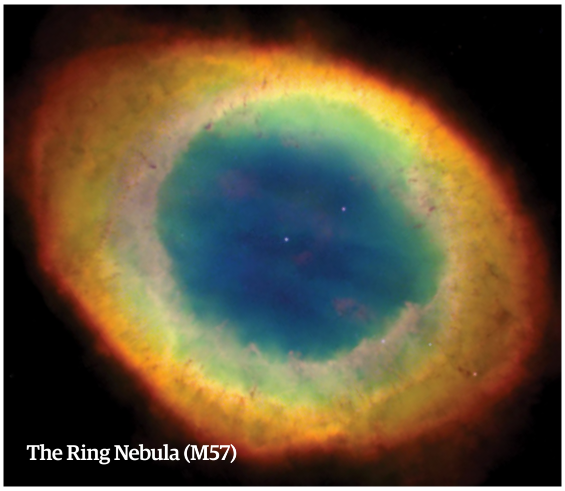
This beautiful and ethereal nebula is a supernova remnant, the remains of an exploded star, and is best viewed with an OIII filter.

4 The Dumbbell Nebula

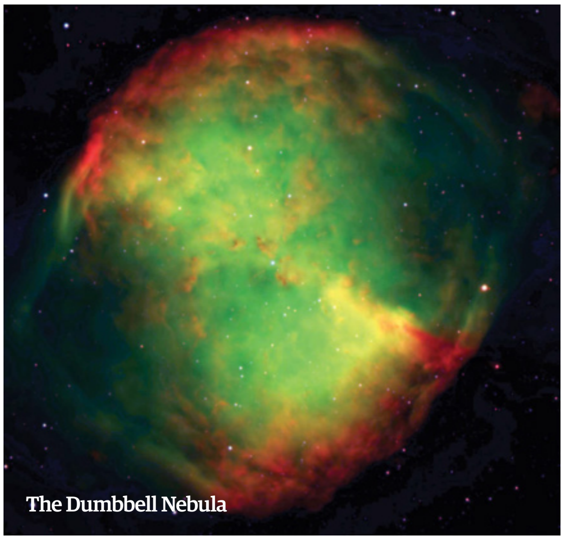
This is another planetary nebula visible in summer, similar to M57 although not as bright. Its narrow waist gives it its name. Again, an OIII filter helps to show it up clearly.

5 Albireo

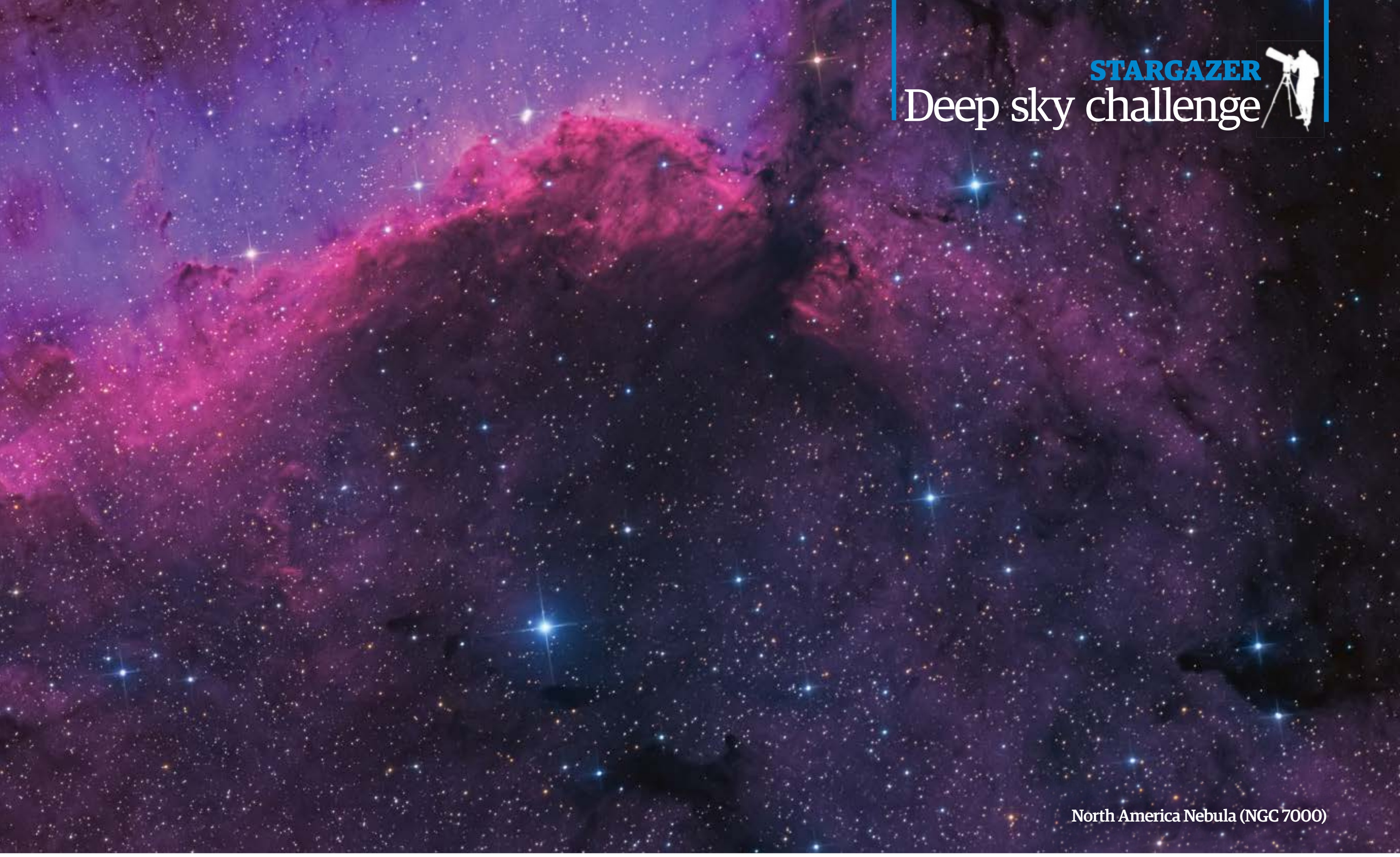
One of the showpiece double stars and easily split by most telescopes, this gorgeous system has a bright orange primary star and a silver secondary star.



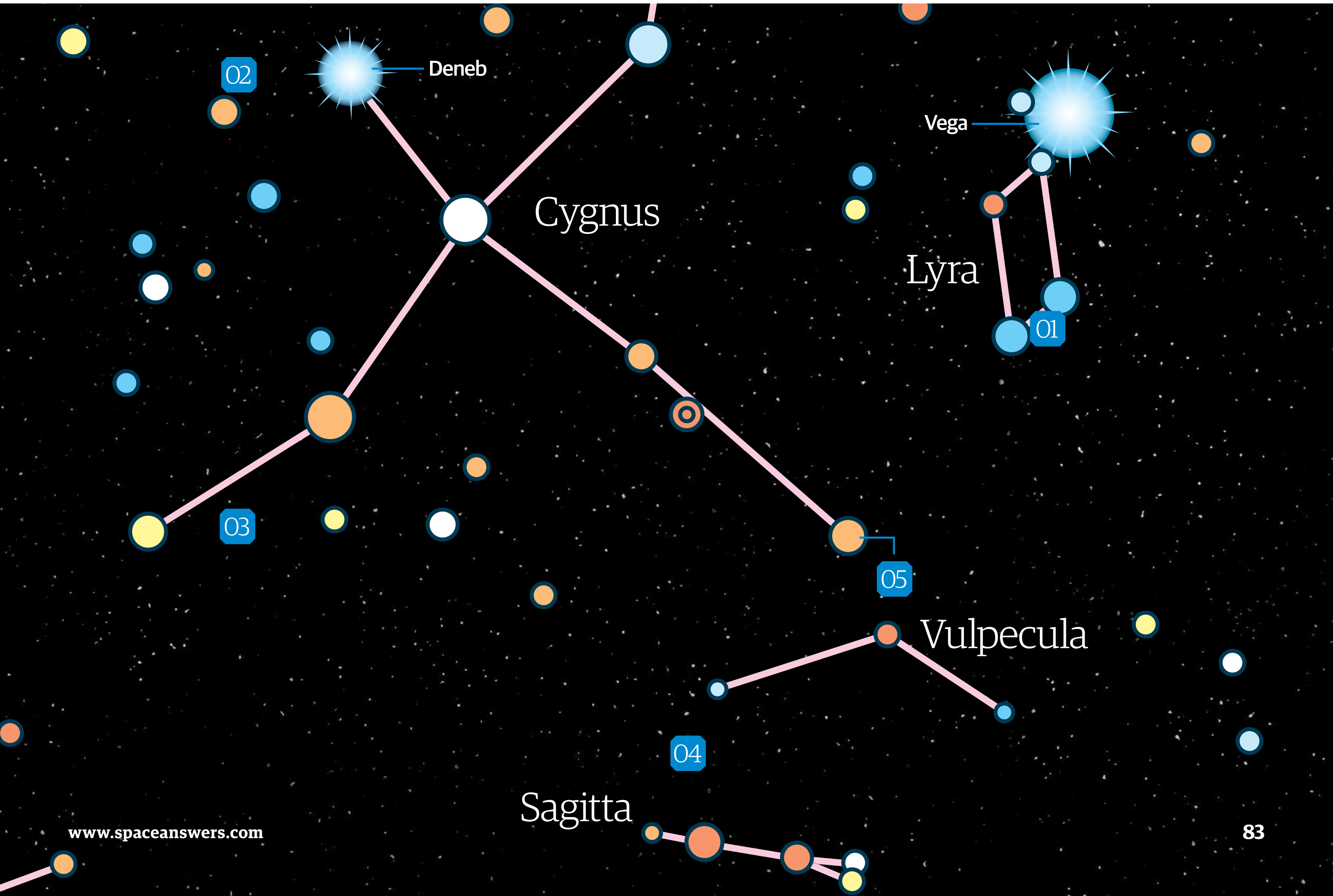
The Ring Nebula (M57)



The Dumbbell Nebula



North America Nebula (NGC 7000)



How to...

Get the best views of sunspots

The Sun is an active star and full of interest for observers with the right equipment

© NASA

You'll need:

- ✔ Small telescope
- ✔ Special solar filter
- ✔ Great care!

Observing the Sun can be fascinating as it is ever changing. Sunspots are what make it so interesting. If you look through a properly filtered telescope, the chances are you will see one or two of these small dark patches, like ink spots on the face of the Sun. Small, that is, relative to the Sun's disc – many of these 'small' spots are larger than the Earth! Occasionally though, you may see a really big one, which would be capable of swallowing several Earths at the same time.

The sunspots follow a cycle that peaks every 10.5 to 11 years. These peaks can see almost constant spot activity, while during the troughs you may be lucky to see just one or two small ones. However, the Sun can be full of surprises and you will never know unless you look.

If you plan to observe the Sun through any optical system, it is vital that you use the correct filters. One glimpse of the unfiltered Sun through a telescope or even binoculars can destroy your eyesight in an instant. There are two or three ways of viewing the Sun through a telescope. The easiest and the safest method is to project the image of the solar disc onto some white card. This way your eye doesn't get near the eyepiece and you can use the scope unfiltered. You can see the spots quite easily on the card and even draw or photograph them.

Another method is to use a device called a 'Herschel Wedge', which fits onto the telescope before the eyepiece and directs away the heat and most of the light using a system of prisms. This then leaves you with an image that is safe to view.

Perhaps the most popular way of seeing the solar disc now though, is by using a white light filter, which fits over the front of the telescope. This can be made from glass with metallic coatings, or metallised film, from which you can make your own filter.

Last of all, you can view the Sun and therefore sunspots through specialist solar telescopes such as the Coronado PST. This uses a very narrow band filter, which shows you the chromosphere, an outer layer of the Sun. The sunspots look a little different through one of these telescopes, but it does allow you to see a lot more detail in both the spots and the solar surface.

Tips & tricks

Use a solar filter

Always use the proper type of solar filter. These are usually available from specialist telescope suppliers.

Observe safely

Check your solar filters regularly and before you use them on the Sun. If in doubt, don't use them!

Check the solar cycle

Find out where in the solar cycle we are. This will give you an idea about how many sunspots you might see.

Use the 'least shadow' method

Aiming your telescope at the Sun can be difficult. The easiest way to do this is to use the 'least shadow' method.

Be aware of overheating

Don't aim your scope at the Sun for too long as the heat can damage the optics.

Improve your chances of seeing sunspots

Knowledge and safety are the most important things when viewing the Sun

Finding out when there are sunspots on the solar disc is obviously important and there are several websites with up-to-date information. You can also find detailed information about making safe solar filters and how to use your telescope to project the Sun's image.

With regards to safety, this is *the* most important issue when it comes to solar observing. If you have any doubts about what you are using, or how to use it, please seek out proper advice, either from a telescope dealership, a local astronomical society, or the British Astronomical Association.

Send your photos to
photos@spaceanswers.com

1 **Fit a solar filter**
If you're using a solar filter to observe the sunspots, make sure the filter is fitted securely and correctly, and is added when the telescope is pointing away from the Sun.

2 **Cap off your finderscope**
Make sure that any finderscope on your telescope is firmly capped off. This is to make sure that you don't use it by mistake, as a glimpse of the Sun could permanently damage your eyes.

3 **Safely aim your scope at the Sun**
Move the telescope around while watching its shadow on the ground. When the shadow disappears, your scope is pointing at the Sun. This is called the 'least shadow' method.

4 **Use the right magnification**
Use a low power eyepiece at first to centre up the Sun in the field of view. Then you can increase the magnification to get a better view.

5 **Communicate safe solar observing**
If you are showing the Sun and its sunspots to any children, be sure to explain the dangers of looking at the Sun through any unfiltered optics.

6 **Record the view**
You can easily draw the position of the sunspots and follow their motion each day, as well as track their appearances.

The Northern Hemisphere

The summer skies are alive with star clusters and a smattering of galaxies this month

Leaving July and heading into August, the summer skies still offer a lot in the way of deep-sky objects for astronomers who enjoy observing the night sky in the late evening and into the small hours.

As well as the nebulae of the summer, the star clusters of Cygnus, Hercules and low-on-the-horizon Ophiuchus, and the galaxies of Ursa Major are excellent pickings for observers with binoculars and telescopes. August, in particular, is an ideal time to observe our nearest spiral, the Andromeda Galaxy (M31). The star clusters NGC 884, NGC 7686 and NGC 1502 of Perseus, Andromeda and Camelopardalis respectively, are good targets in the early hours.

At varying times of the night, the naked eye planets will make their way along the ecliptic. Remember to use this map under red light to preserve your night vision.

Using the sky chart

This chart is for use at 10pm (BST) mid-month and is set for 52° latitude.

01 Hold the chart above your head with the bottom of the page in front of you.

02 Face south and notice that north on the chart is behind you.

03 The constellations on the chart should now match what you see in the sky.

Magnitudes

- Sirius (-1.4)
- -0.5 to 0.0
- 0.0 to 0.5
- 0.5 to 1.0
- 1.0 to 1.5
- 1.5 to 2.0
- 2.0 to 2.5
- 2.5 to 3.0
- 3.0 to 3.5
- 3.5 to 4.0
- 4.0 to 4.5
- Fainter
- Variable star

Spectral types

● O-B

● A

● F

● G

● K

● M

Deep-sky objects

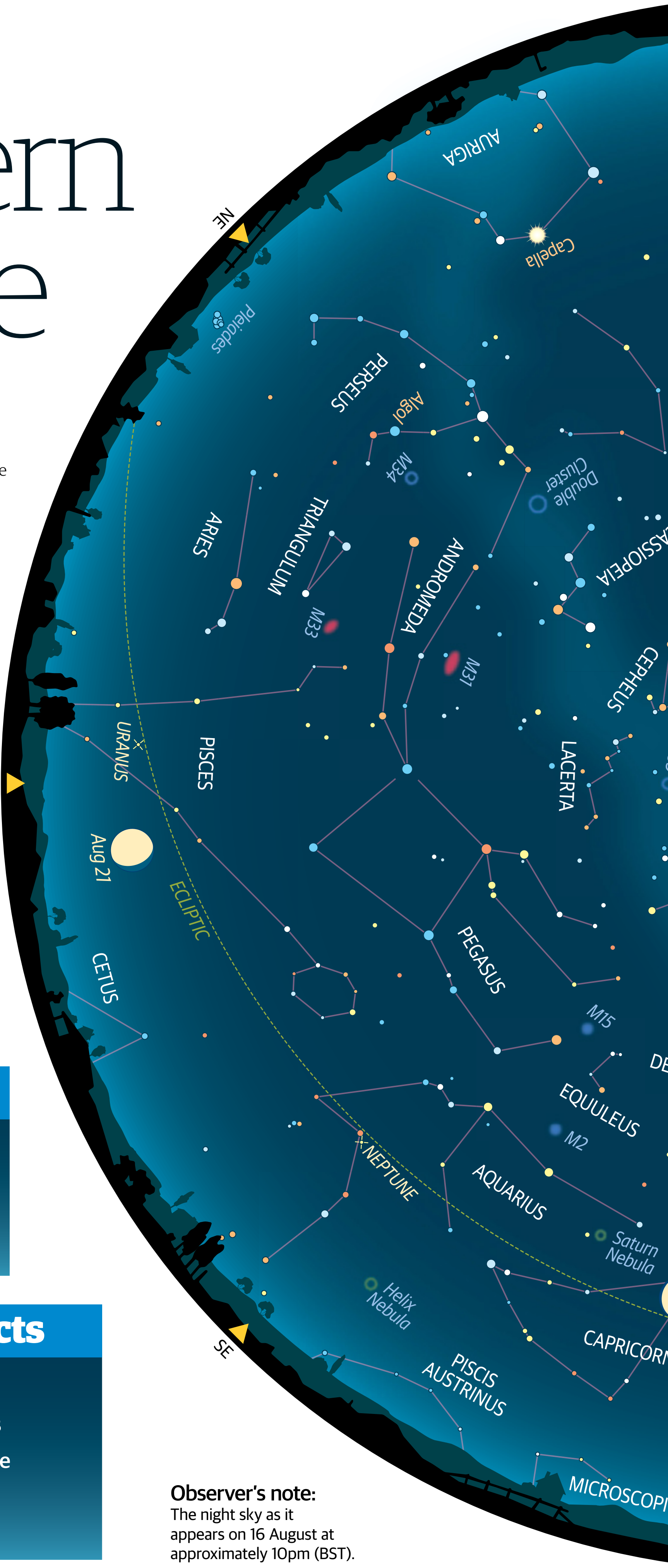
○ Open star clusters

● Globular star clusters

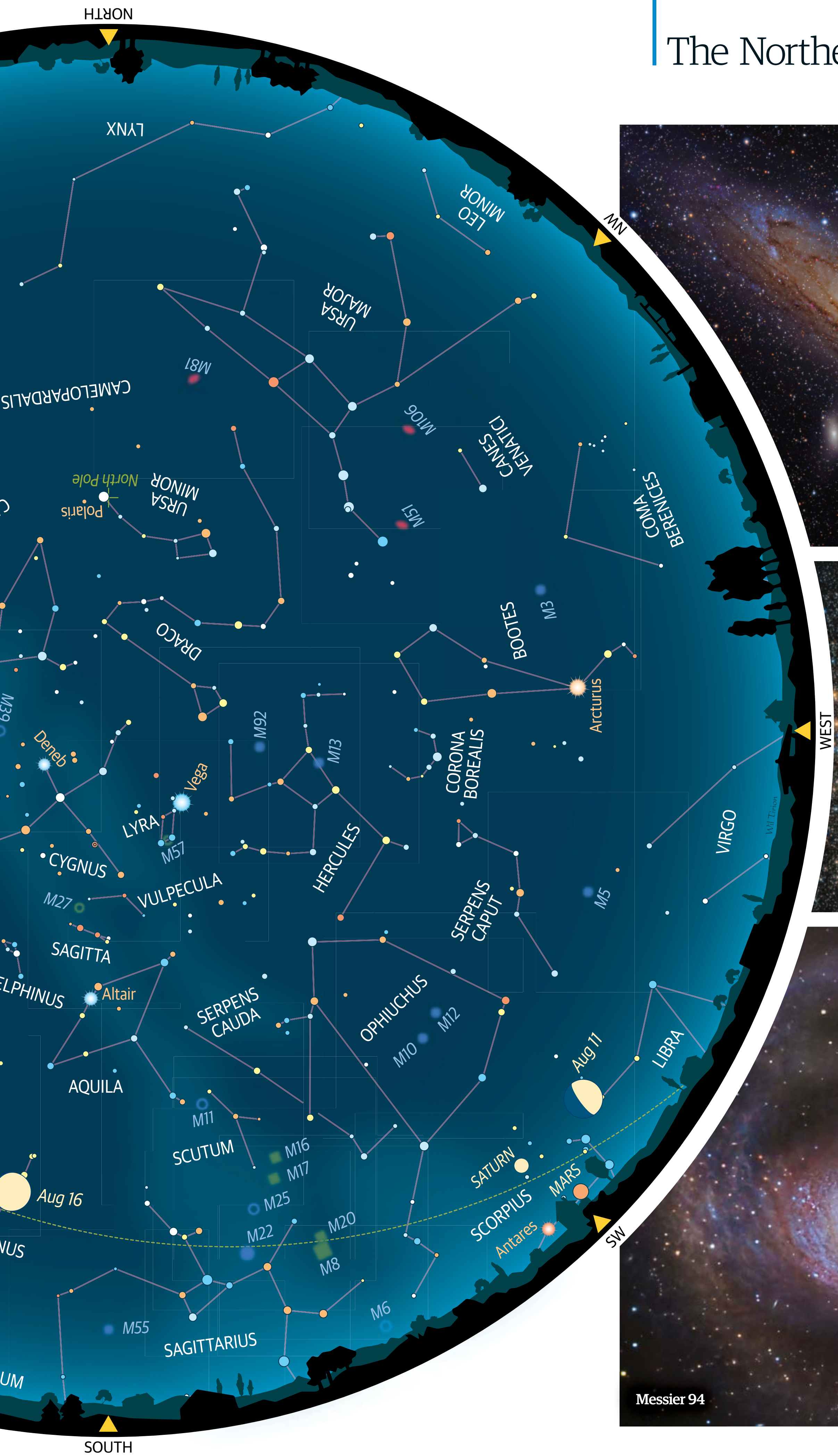
🟩 Bright diffuse nebulae

○ Planetary nebulae

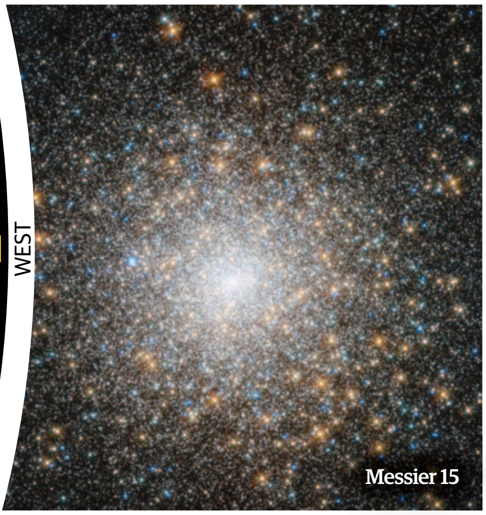
● Galaxies



Observer's note:
The night sky as it appears on 16 August at approximately 10pm (BST).

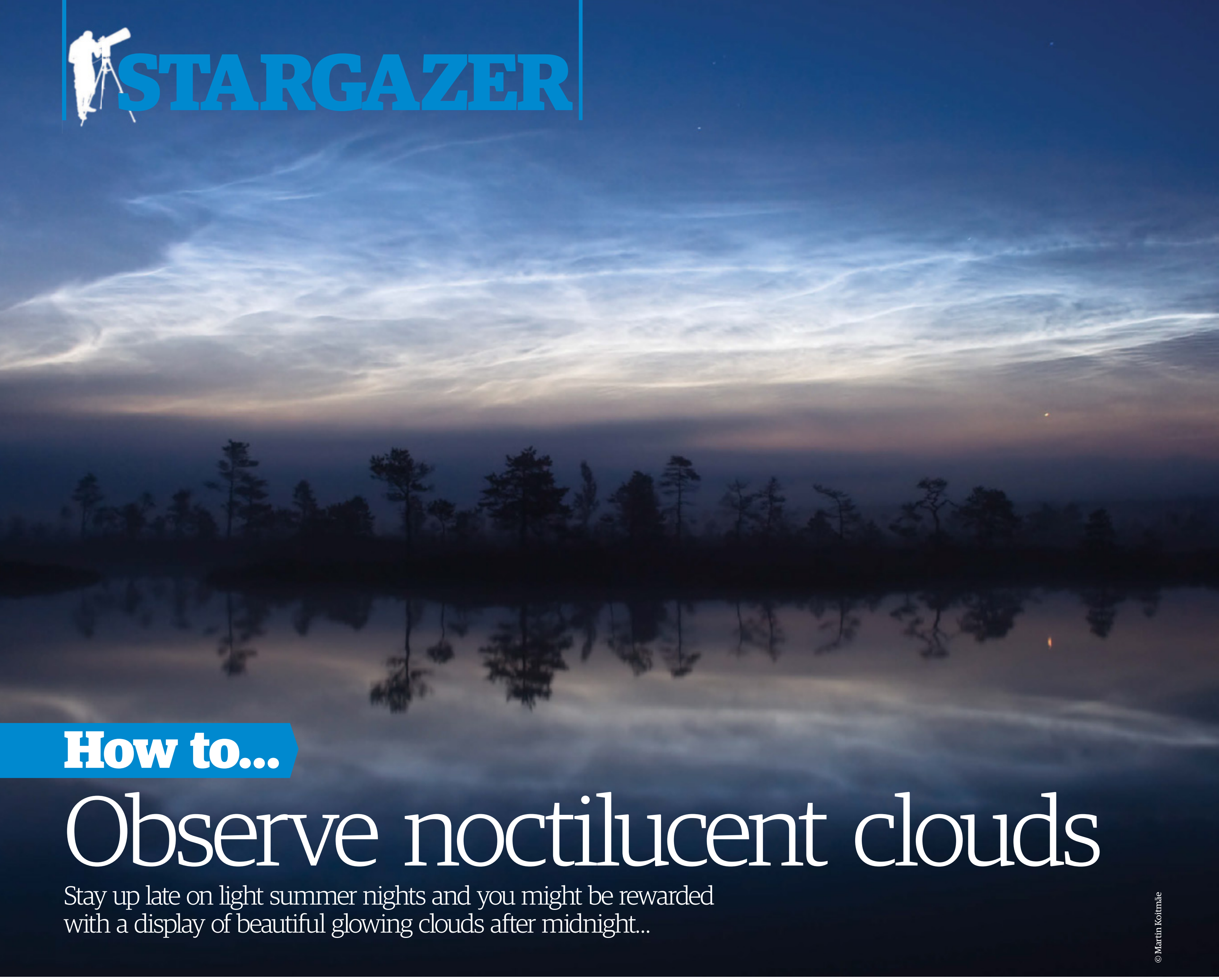


Andromeda Galaxy (M31)


Messier 15

Messier 94

© Wil Tirion; NASA; ESA; Adam Evans; R Jay Gabany



© Martin Koitmäe

How to...

Observe noctilucent clouds

Stay up late on light summer nights and you might be rewarded with a display of beautiful glowing clouds after midnight...

You'll need:

- ✔ A clear view to the north
- ✔ Binoculars
- ✔ A camera or smartphone
- ✔ A lot of patience!

Light and warm summer nights make it hard to see many of the faint galaxies, nebulae and clusters we enjoy observing at other times of the year, but there's no need to go into astronomical hibernation.

Summer is the only time we can see one of the most stunning sights in the sky – a display of beautiful silvery-blue noctilucent clouds. However, these phenomena don't appear every night, and unlike the aurorae, they cannot be predicted, meaning that observers need to keep an eye on the sky in case a display is in progress. Noctilucent clouds are often visible somewhere with a clear view north and without any obstructions on the horizon, as they tend to stay quite low in the sky.

Noctilucent clouds – or NLC as they're often called – are, as their Latin name suggests, 'night-glowing' clouds. Made of ice-coated dust, probably micro-meteoritic in origin, at a height of between 76 and 85 kilometres (47 and 53 miles), they are the highest clouds that form in our atmosphere. It's their extreme altitude that makes them visible: they are bathed in sunlight long after night has fallen down here on the ground.

But they only come into view when the Sun is at least six degrees below the horizon, which means they don't appear until very late on summer evenings. So, like watching meteor showers, observing NLC means staying up late, and sometimes all night; a major display can last right through the night until the sky brightens with the approach of dawn.

Most NLC just look like wispy tendrils of smoke running parallel to the horizon, much like the cirrus clouds we see in the daytime. But bigger displays fill the northern sky with intricate whirls, curls and swirls of light. Some areas are rippled, like the sand ripples you see on the beach. Other areas are bunched up into knots and loops, or look like a fishing net, shining with a unique electric silvery-blue light.

You don't need special equipment to watch NLC as they're a naked eye treat, but a pair of binoculars will help you to see their exquisite structure, enhance their colour and show you their subtle movement, too. They are also great photographic subjects, especially if you have an interesting foreground to contrast them against.

A DSLR camera on a tripod will get fantastic shots of the noctilucent clouds, but your smartphone's camera will pick up the brightest displays, too.

Tips & tricks

Find a good viewing site

You'll have more chance of seeing NLC from somewhere with a clear view of the horizon to the north.

Find out Capella's location

NLC tend to first appear beneath and around the bright star Capella, so learn where to find Capella in the sky to make sure you're looking in the right direction.

Take a pair of binoculars

NLC can be obvious to the naked eye, but binoculars will help you spot faint clouds and also show the fascinating structures within the brighter displays.

Keep up to date

Follow NLC watchers on social media so you don't miss the next big display. Some even post observing reports and photographs during displays.

Take photographs

Some displays of NLC are bright enough to capture with your smartphone.

Viewing noctilucent clouds

Catch beautiful displays in the summer sky

Observing noctilucent clouds is a lot like observing meteor showers - you have to have a lot of patience and be prepared to lose sleep.

If a really big display occurs, you might end up staying awake right through the night and into the small hours of the next morning to see these eerie displays. But it's certainly worth yawning all through the next day to see one of the most beautiful sights in the night sky. Here's how you can be prepared for the next big display.

Send your photos to
photos@spaceanswers.com

1 Find a good observing site in advance

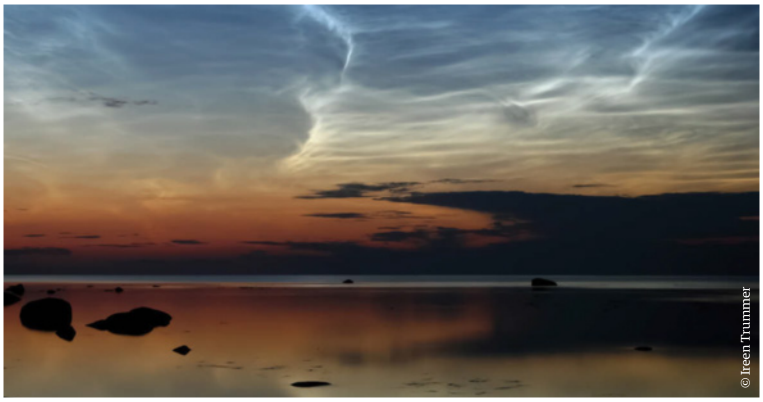
A location with little light pollution and a clear view to the north, without any hills, buildings or tall trees on the horizon, will provide the best chance of seeing NLC. You can find a good site during the daytime.

2 Start observing at the right time

NLC only appear when the Sun is more than six degrees beneath the horizon, so there's no point looking for them too early. Start around 11pm - and keep looking as long as you can.

3 Use the star Capella as a guide

If you look towards the bright star Capella, you'll be looking in the right direction. Sweep that part of the sky with binoculars in case there are any NLC too faint for your eyes to see.



© Ireen Trummer

4 Know what you're looking for

NLC will look like delicate wisps of electric blue-white in the sky. They are unlike 'normal' clouds, which are dark and may even be silhouetted in front of the NLC. Always look in gaps in the cloud, too.

5 Take some photographs

A bright and beautiful display of NLC can be captured using just the camera on your smartphone or tablet. A DSLR on a tripod will let you focus more sharply and record fine detail within the clouds, for a more professional image.

6 Don't give up too soon

If a display fades and drops beneath the horizon, don't just pack up and go home. NLC can return brighter and bigger than before. Also, look to the east before dawn for morning displays.

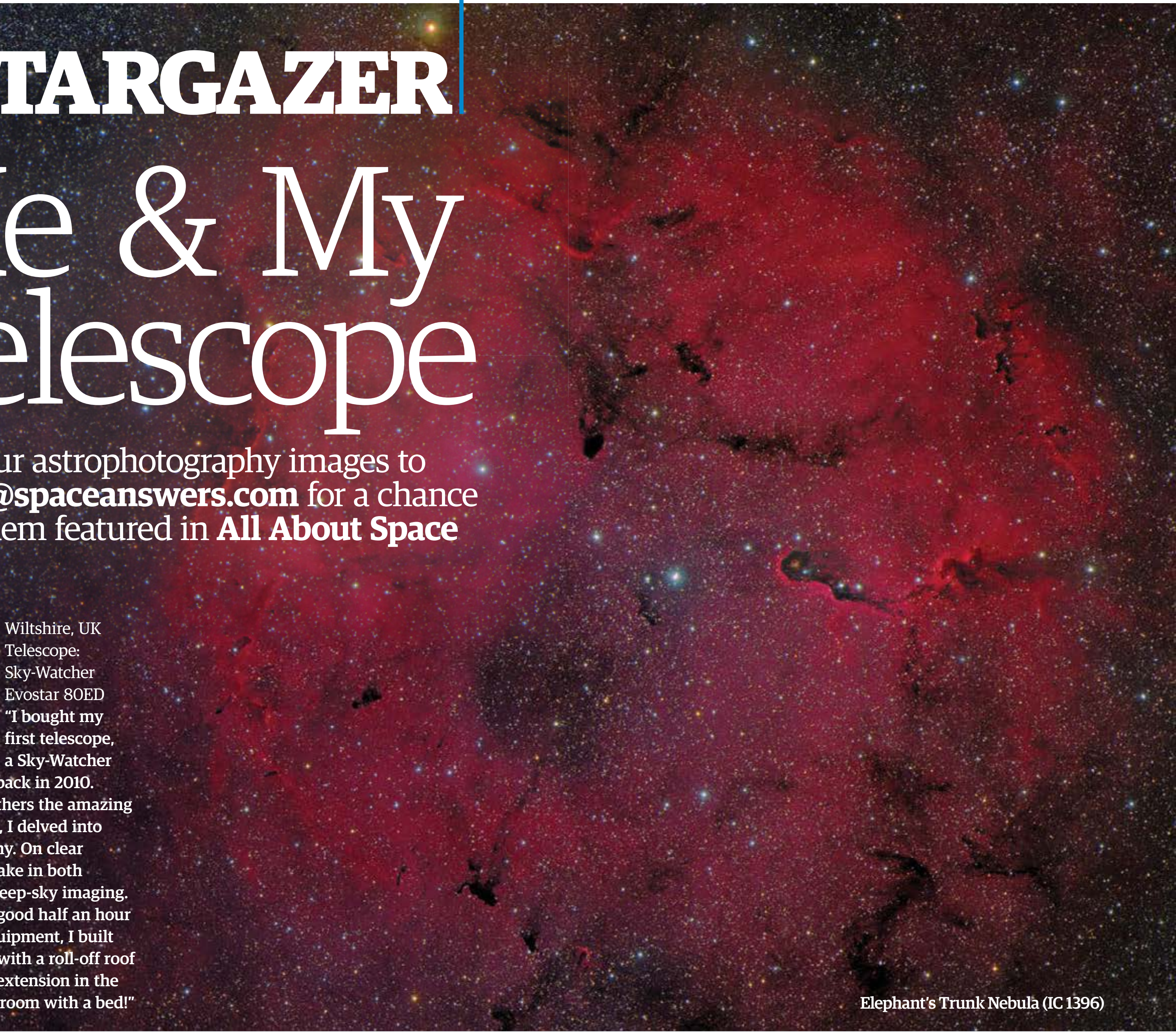
Me & My Telescope

Send your astrophotography images to **photos@spaceanswers.com** for a chance to see them featured in **All About Space**

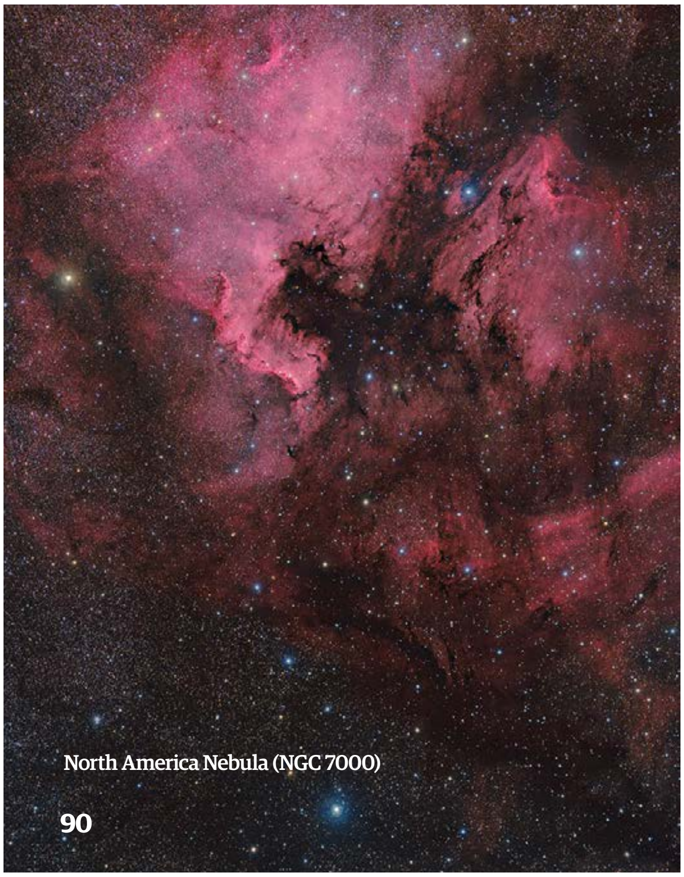
Bob Ford

Wiltshire, UK
Telescope: Sky-Watcher Evostar 80ED

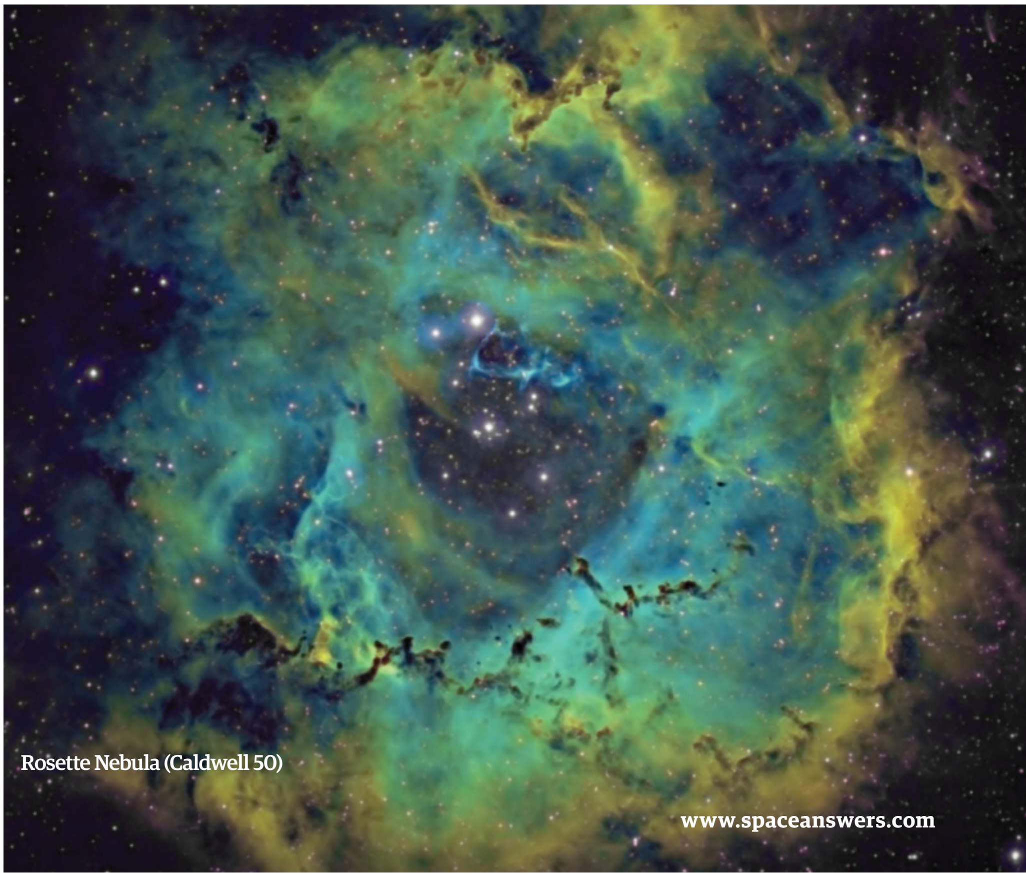
"I bought my first telescope, a Sky-Watcher Explorer 200P, back in 2010. Keen to show others the amazing objects in space, I delved into astrophotography. On clear evenings, I partake in both planetary and deep-sky imaging. Since it takes a good half an hour to set up my equipment, I built an observatory with a roll-off roof - it now has an extension in the form of a warm room with a bed!"



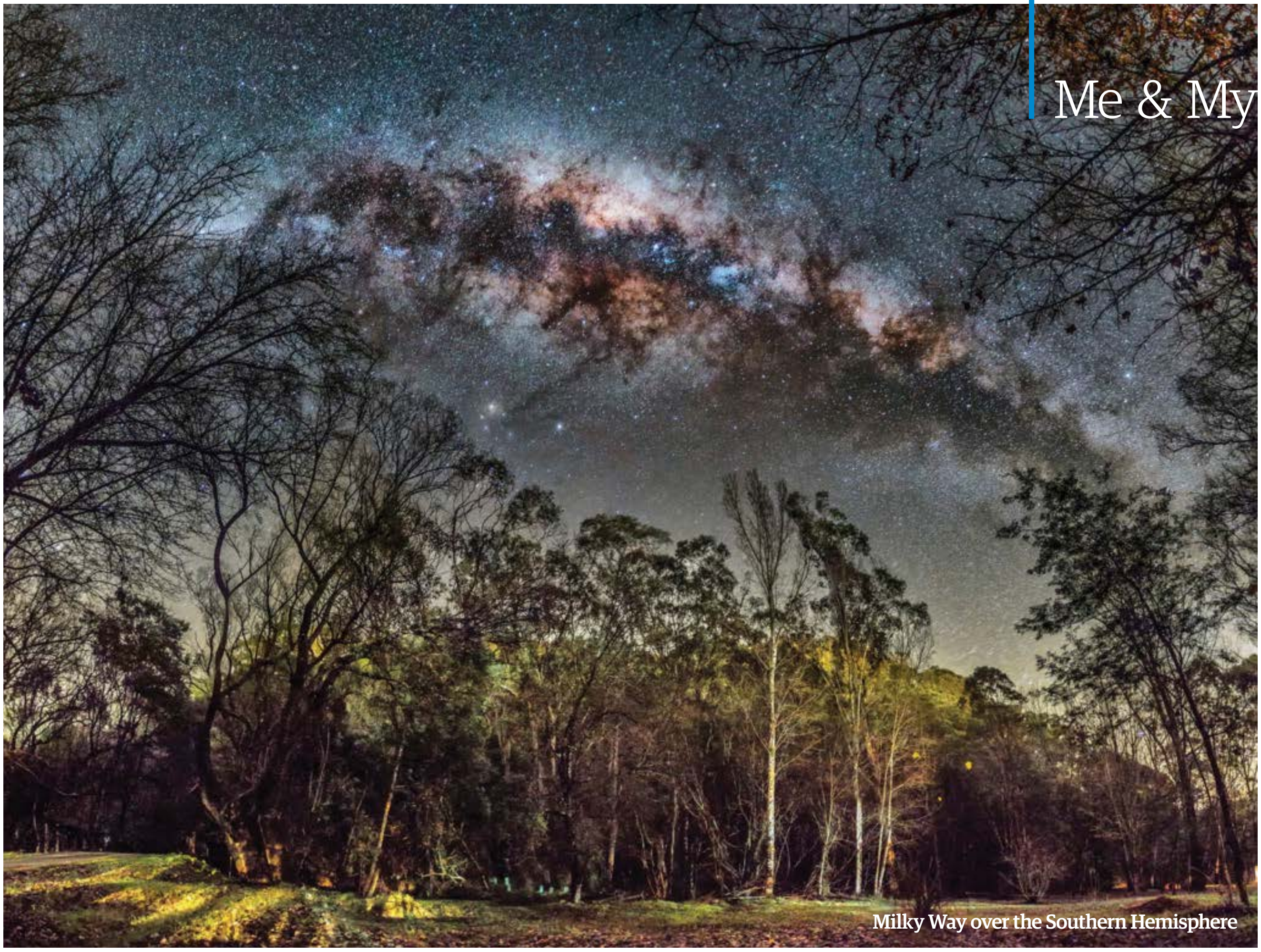
Elephant's Trunk Nebula (IC 1396)



North America Nebula (NGC 7000)



Rosette Nebula (Caldwell 50)



Milky Way over the Southern Hemisphere

Hamed Fayeghi

Harrietville, Australia

"The night sky, specifically the Milky Way, has always been one of my favourite subjects for astrophotography. Before moving to Australia, I was very unfamiliar with the Southern Hemisphere night sky but realised quite quickly when I stood under it that it appears very different to the Northern Hemisphere - you can see a much more beautiful portion of our galaxy as well as the Magellanic Clouds. While the evening skies are beautiful in this part of the world, the galactic core can be a challenge to observe during the autumn and winter months since it is usually cloudy. This image reflects just a corner of our beautiful sky."

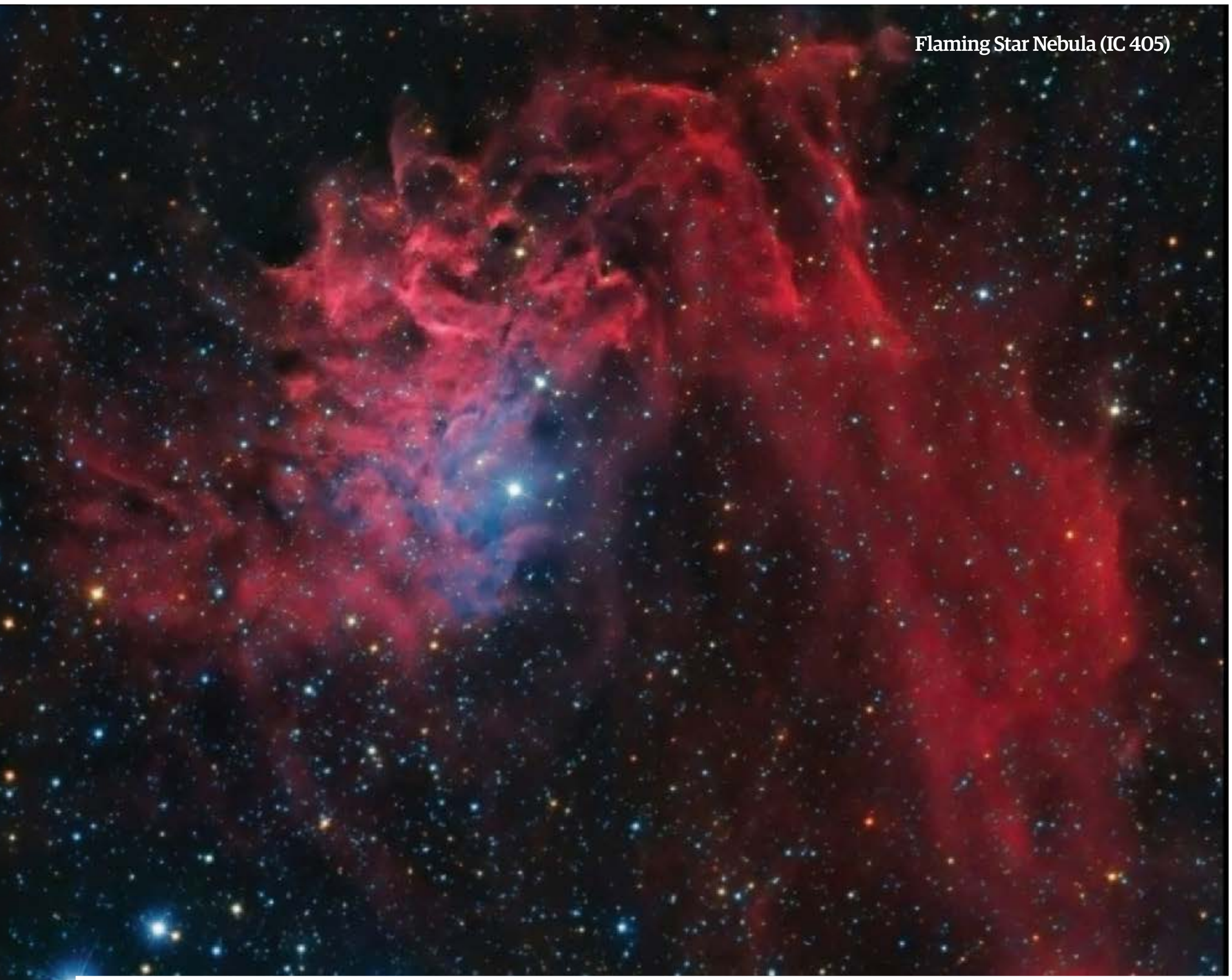
Terry Hancock

Michigan, US

Telescope: 12" Ritchey-Chrétien reflector and Takahashi E180 Astrograph

"This image is a new process of one of my favourite targets, where, for the first time, I used Pixinsight for pre-processing. I'm unsure if I can say that this process helped or improved the image, but in the final analysis I have tried to keep the image looking as natural as possible.

Also known as IC 405 and Caldwell 31, the Flaming Star Nebula rests some 1,500 light years away in the constellation of Auriga and is a combination of emission and reflection nebulae."



Flaming Star Nebula (IC 405)

Send your photos to... @spaceanswers @ photos@spaceanswers.com

Visionary STARLA 80

A refractor that's ideal for observing the Solar System, the STARLA 80 is an affordable telescope for the beginner

Telescope advice

Cost: £199.99 (approx. $260)
From: Optical Hardware Ltd
Type: Refractor
Aperture: 3.15"
Focal length: 35.43"

Best for...

- ? Beginners
- £ Small budget
- Planetary viewing
- Lunar viewing
- Double stars
- Bright deep-sky objects

The Visionary STARLA 80 from Optical Hardware Ltd is a good telescope for those not wishing to spend a fortune, yet who still want to view a variety of night-sky targets that are also at naked eye magnitude. This refractor is also ideal for children thanks to its lightweight build for easy portability and its simple setup.

Indeed, putting the telescope together is nothing short of a breeze. Within just ten minutes, and without the need for the supplied instructions, we had set it all up and were ready to test its mettle on a selection of night-sky targets.

Before setting out to observe the July night sky, we studied the build of the STARLA 80. For the price, the general construction is fair but some of the 'add-ons', such as the star diagonal are quite flimsy. Trying to fasten it to the main tube posed a bit of a challenge and despite our best efforts to fasten it into place with the supplied screws, this particular piece of the telescope wobbled and even fell out when we slotted an eyepiece into it. There are a great deal of light plastic fixtures on the telescope, but for a retail value of only £200 (approximately $260) for a complete outfit, this really is to be expected to keep the manufacturing costs low.

We noted the alt-azimuth mount that promised easy use for the novice astronomer, which can simply be replaced for the slightly more advanced equatorial mount due to the combined versatility of the tripod and Vixen dovetail under the telescope tube. If you eventually want to replace the alt-azimuth mount though, then we recommend purchasing an equatorial mount that's relatively light, given that the STARLA 80 itself will topple over quite easily if it is unbalanced. The supplied 1.25" Plössl eyepieces of focal lengths 10mm and 25mm (which provide magnifications of 90x and 36x respectively) are of a good, robust quality.

The Visionary STARLA 80 lives up to its appearance of being portable as we picked it up with no effort and took it outside for an evening of observing. Indeed, the refractor is ideal as a simple grab-and-go telescope that can be thrown into the car or carried to a dark-sky site.

A waxing gibbous Moon had risen in the sky as we placed the telescope on an even patio floor. The 5x24 finderscope, which is simple to calibrate, pointed us in the right direction and it wasn't long before we found ourselves at the centre of the lunar sea, Mare Tranquillitatis (Sea of Tranquillity). Views were decent as we began our tour of the rugged surface, as bright impact craters sprang into the field of view. Before catching a very good view of the crater, Tycho, we couldn't resist tracing our way along the terminator for a display of craters dramatically played up in the shadows and the Sun's light. Overall, views were clear, but we couldn't help but notice purple colour fringing along the lunar limb. Unless you are looking for flaws in the telescope's optical system though, this doesn't spoil the view.

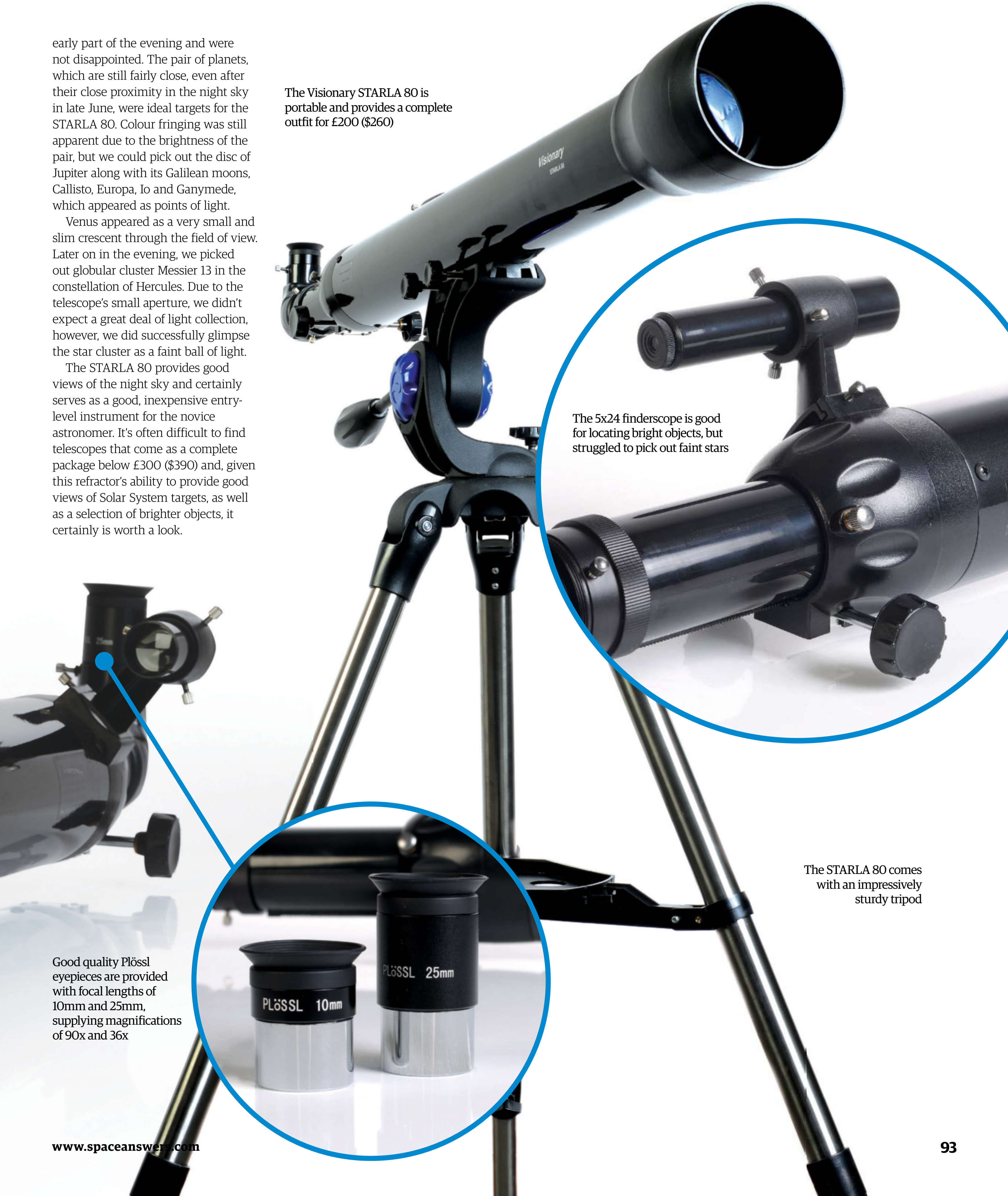
Heading away from the Moon, we moved away from its brightness in an attempt to test the STARLA 80's capability of observing fainter targets. The finderscope struggled to pick out fainter stars meaning that star hopping with this telescope is out of the question. We do believe that users of this refractor will get much more satisfaction from a red dot finder when it comes to locating targets in the night sky.

We waited until the following night to catch Venus and Jupiter in the

For an entry-level telescope, observations are pleasing, however, there is a degree of colour fringing when the telescope is turned toward bright targets early part of the evening and were not disappointed. The pair of planets, which are still fairly close, even after their close proximity in the night sky in late June, were ideal targets for the STARLA 80. Colour fringing was still apparent due to the brightness of the pair, but we could pick out the disc of Jupiter along with its Galilean moons, Callisto, Europa, Io and Ganymede, which appeared as points of light.

Venus appeared as a very small and slim crescent through the field of view. Later on in the evening, we picked out globular cluster Messier 13 in the constellation of Hercules. Due to the telescope's small aperture, we didn't expect a great deal of light collection, however, we did successfully glimpse the star cluster as a faint ball of light.

The STARLA 80 provides good views of the night sky and certainly serves as a good, inexpensive entry-level instrument for the novice astronomer. It's often difficult to find telescopes that come as a complete package below £300 ($390) and, given this refractor's ability to provide good views of Solar System targets, as well as a selection of brighter objects, it certainly is worth a look.



The Visionary STARLA 80 is portable and provides a complete outfit for £200 ($260)

The 5x24 finderscope is good for locating bright objects, but struggled to pick out faint stars

The STARLA 80 comes with an impressively sturdy tripod

Good quality Plössl eyepieces are provided with focal lengths of 10mm and 25mm, supplying magnifications of 90x and 36x

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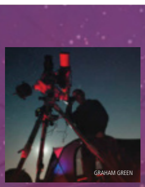

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Book

Month-By-Month Stargazing 2016

Cost: £6.99 (approx. $9.05)

From: Philip's Astronomy

Written by astronomers Heather Couper and Nigel Henbest, *Month-by-Month Stargazing 2016* does exactly what it says on the tin: helping sky-watchers to see this year's most exciting events with the naked eye, binoculars or a telescope.

Stargazing 2016 is suitable for observers between latitudes 40 degrees north and 60 degrees north, which includes the UK, Ireland and Europe as far south as Rome, as well as Canada and the northern portion of the United States, as far south as Philadelphia. With each section of the book divided up by the months of the year, Couper and Henbest's offering is easy to follow, making it a good guide for the novice astronomer who is just learning their way around the night sky.

What's more, the sky charts seem to manage well under red light, meaning that you can use this handy guide during observing sessions without ruining your dark-adapted vision. While many of the year's must-see astronomical events seem to be included, we did notice that details on Comet Lovejoy were missing. The authors have included extras in this concise handbook, with information on Solar System and deep-sky objects, as well as advice on choosing your equipment and dealing with light pollution.

App

Space Junk Pro

Cost: £3.99 (approx. $5.20)

From: Google Play & iTunes

This handy app for your smartphone, available for both Android and iOS devices, uses satellite data to reveal the features of the night sky above you, from the locations of planets to satellites and constellations visible from your location. If you are keen to get outside and view the International Space Station as it races around our planet in its orbit, or even catch a glimpse of the Hubble Space Telescope, then this low-cost app is a sure favourite. When using the app, ensure that the compass on your smartphone is fully calibrated to get an accurate view of the night sky above you. While the app uploaded smoothly to our device, it did drain the iPhone's battery quite quickly, so make sure your smartphone is fully charged before setting out on an observing session. Overall, however, Space Junk Pro offers a comprehensive and useful piece of software for sky-watchers at an affordable price.

App
Star Walk

Cost: £2.29 ($2.99)
From: iTunes

If you have difficulty finding your way around the night sky and you can't afford a GoTo, then Star Walk is the next best thing since it's able to work out the exact location as well as the celestial object that you point your iPhone at. Of course, it works in reverse too, by helping you to find the object that you wish to locate.

Using a GoTo, we followed up the Right Ascension and Declination coordinates to see how accurate it was and were impressed to find that, on harnessing the iPhone's GPS capabilities, it was almost spot-on. We're based in the Northern Hemisphere, but that didn't stop us from checking out the stars and constellations in the South as we pointed Star Walk downwards and were treated to the positions of countless objects in the Southern Hemisphere. Additionally, the touch screen allowed us to learn more about the objects we were viewing – excellent for users wanting to learn their way around the night sky.

Sky Tracker
Vixen Polarie Star Tracker

Cost: £399.00 (approx. $516.60)
From: Opticron

If you're an astrophotographer that gravitates towards a DSLR camera for wide-angle night-sky shots rather than a CMOS or CCD for deep sky and planetary viewing, then the Vixen Polarie is a very rewarding purchase for capturing the dusty trail of the Milky Way and other large field shots – without having to worry about the Earth's rotation blurring imagery of the heavens. This Star Tracker can be used in both the Northern and Southern Hemispheres. We enjoyed the design of the Polarie's outer casing, which featured the Plough, or Big Dipper, on an extremely well manufactured case.

The Vixen Polarie Star Tracker is powered by two AA batteries, which allowed it to operate for roughly two hours and provided nonrestricted use. Sadly, the Star Tracker did not come with a cable, which meant that we had to carry a large number of batteries with us to prevent the tracker from running out of power during a full night of astronomical observation and imaging.

The Star Tracker held a Canon EOS 70D with no problems at all and we found the integrated compass to be extremely useful. Once set up, we were able to achieve very good image results, with the Milky Way's stars pinpointed with ease as the Star Tracker worked against the rotation of our planet. It is perfect for anyone in need of assistance with nightscape imaging.

© National Air and Space museum

Bean was the youngest person to walk on the Moon until Charlie Duke stepped foot on the lunar surface in 1972

Alan Bean

He is the Moon-landing astronaut-cum-artist who became the first to paint humans in space

To date, just 12 people have walked on the Moon; Alan Bean was the fourth. As the lunar module pilot on Apollo 12, he followed in the footsteps of his mission commander Pete Conrad on 19 November 1969. The pair spent two days exploring the Moon, gathering rocks from the Ocean of Storms and taking ten kilograms (22 pounds) of hardware from the unmanned Surveyor 3 spacecraft, which had landed two years earlier. They were also asked to take photographs. But Bean would end up going a little further than that.

Born on 15 March 1932, Bean grew up in Texas and he developed a love of flying. After graduating from the University of Texas with a degree in Aeronautical Engineering, he entered the US Navy and became a fighter pilot for four years before taking on the risky role of test pilot. He logged 7,145 hours of flying time in total and enjoyed his time in the air. Yet his ambition was to reach for the stars so he applied to become an astronaut, only to find himself sitting on the sidelines for a number of years.

Bean's chance would eventually come but under the saddest of circumstances. Clifton Curtis Williams, who had been chosen to be the lunar module pilot for the Apollo 9 back-up crew, was killed in a plane crash caused by a mechanical failure on 5 October 1967. Bean was offered the role and he seized the opportunity to take his place. The back-up crew ended up flying as Apollo 12 and, despite a lightning strike just 36 seconds after lift-off, the mission was a resounding success. Bean and Conrad piloted the lunar module, Intrepid, close to Surveyor 3 and even managed to install the first nuclear power generator station on the Moon. Bean was aged just 37.

Four years later, Bean became the commander of the Skylab 3 mission, which was the second manned mission to the space station and ran between 29 July and 25 September 1973. The crew set a record for the longest flight, having travelled 39.2 million kilometres (24.4 million miles) in 59 days, and Bean performed a spacewalk. With another successful mission under his belt, he was assigned as the back-up US spacecraft commander for the joint American-Russian Apollo-Soyuz Test Project.

Although he had resigned from the Navy in 1975, Bean stayed with NASA as chief of the astronaut candidate operations and training group. That lasted for six years when, in 1981, having logged 1,671 hours and 45 minutes in space, he decided to leave NASA and become a full time artist: a career path that deviated wildly from the science-based pursuits his colleagues have tended to take.

While this came as a surprise to his colleagues, there was no doubting Bean's passion. Even before he had begun his space shuttle pilot training, he'd spent a lot of time painting subjects on Earth and had attended night school to study his craft.

Space had broadened his horizons however, and it allowed him to create artwork from a perspective that was very much out-of-this-world. He became the first artist to be able to draw upon his own first-hand experiences in painting depictions of space. What's more, he has developed his own technique, sculpting textured surfaces on his art using lunar tools.

Not content with a brush, he uses a lunar hammer and Apollo boots and he infuses real Moon dust into many of his creations. He has also added heat shield particles and gold foil from the Apollo 12 Command Module. As well as selling for thousands of dollars, Bean's work has been exhibited at the Smithsonian National Air and Space Museum in Washington D.C. You can view them for yourself at **www.alanbean.com**.

All About Space

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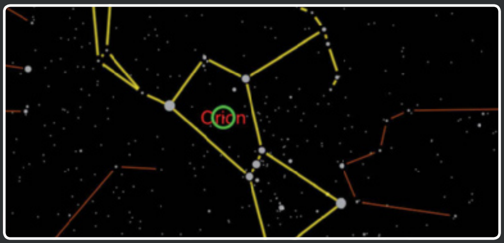

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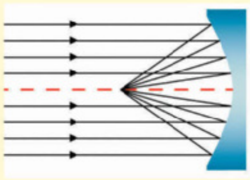

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